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Atoms in the Crystal Model

Masters Thesis

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by

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Acknowledgments

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Helplessness guides the wandering thought in their breasts; they are carried along deaf and blind alike, dazed, beasts without judgment, convinced that to be and not to be are the same and not the same, and that the road of all things is a backward-turning one. (Parmenides)

Abstract

The crystal theory is about helping physics and chemistry with their many established results, with the emphasis on not depending so much on speculative properties but more on solid experimental work. Here we investigate mainly the stable and semi-stable isotopes of many atoms together with the chemical shell structure of the atomic electron cloud. The crystal theory does not model a nucleus and separate disjoint shells of electrons, but rather it considers an amalgamation of the two into one unit. After Einstein helped develop the theories of general relativity and also obtained a Nobel prize for developing the quantum mechanics of light he realized how incompatible these various theories were: action at a distance via mysterious fields and quantum entanglements was very puzzling. He searched in vain for some mechanism while quantum theorists gave advice that such mechanisms were impossible inside the current standard model and QM setups because of "no-go theorems" such as Bell-Kochen-Specker. These no-go's are avoided in the crystal model because we believe that geometry (the Hilbert spaces and fields of forces and particles in the standard model) shouldn't be assumed as a fact, always holding despite what scale is used. Although the crystal appears to be embedded into a standard 3-d Euclidean space with a body-centred cubic structure, the actual coordinates are not related directly to standard space, but to the properties time, magnetism and energy. There should be transformations that go from the crystal space to the standard "real" space but these are left for further investigation.

We develop the idea that forces (strong, weak, EM) do not operate at a distance via a field (e.g. electromagnetic), but by direct contact in a crystal structure that determines the various structural possibilities. It is assumed that the particles, atoms, nuclides and other stable or less stable forms such as neutrinos are bounded by bubbles in the crystal. They satisfy various quantum properties that are not easily modelled in the "real" world: especially spin, parity, charge. Many

of these are conserved in various interactions. Properties such as stability of a particle or atom can be interpreted in the crystal by seeing the shape. We look at interesting isotopes and atoms.

One of the main diversions from the standard model of physics is that the crystal theory has no obvious quark particles. But this might not be a major defect since quarks cannot be directly observed due to quantum chromodynamics. In any case it seems that is possible to explain much of atomic theory without them. The crystal theory gives ways to explain dark matter and many structural parts of quantum mechanics, such as the inability to look inside the nucleus, the meaning of spin (magnetism), charge and parity, and the existence of electron shells with their subshells, orbitals, pairings, energy levels, Pauli exclusion principle, Hund's rule for filling orbitals. We look at the formation of carbon-12 (a main component of life) and give the crystal interpretation of how it can be formed from three helium nuclides via the unstable Hoyle carbon state.

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Chapter 1 Introduction

1.1 Philosophy and assumptions

A theory can have a grain of truth, but sesame or poppy? (Glynn)

Physics and chemistry assume that there is movement in space by electrons, protons, and neutrons, which can be found in elemental atoms. The crystal theory is about the static structure, as in the philosophy of Parmenides. Discussion of movement can come later when the static forms become convincing. Elements are found in nature in various isotopes, which have the same number of protons but differing numbers of neutrons. Often isomers of these isotopes are detected, where the states of the nucleus are different (usually with different quantum numbers). In this study we will analyse the structure of the elements, making models of the stable or longer-lived observationally stable isotopes and isomers. The model we shall use is subject to three main characteristics. The first comprises the main quantum properties spin and parity which are usually experimentally known (e.g. from NMR data). These determine, often precisely, the positioning of the neutrons and protons within our model. Interaction forces determine the stability or binding energy, and this is analysed using the connection graph which depends on the surfaces involved. Using graph theory, we have already found formulas that use these surfaces to calculate properties such as charge and spin. Second, the chemical properties of atoms are illustrated in the periodic table. We prefer using the “left-step” periodic table of Charles Janet, because it is better suited to our present atomic model, being based on actual filling of electron shells. Finally, mathematical tools such as geometrical transformations that can be used to go between our models and the standard Euclidean space of physics and chemistry. We assume some basic knowledge of

physics and chemistry such as the four quantum numbers that describe the electron shell in an atom. See [1-14].

1.2 Summary of chapters

Chapter one is this introduction. Chapter two contains the basic properties and construction of the crystal and the body-centred cubic lattice in Euclidean space upon which this theory is based and its connection graph. Chapter three goes into more details about the crystal theory and the atom graph paper that is used to more easily describe the particles in it. It has information about the symmetries of the crystal and how they are related to physics. Coordinate systems are used to position the atoms and particles so we can describe them accurately. Handedness (or chirality) of particles is related to reflections in the crystal. The fundamental tetrahedra that comprise the crystal are given a quantum mechanical spin that is related to the ordering of the vertices in two ways. The parity of atoms and electrons is explained via positioning within the crystal and the various directions up or down. The quantum numbers of the shells and subshells in chemistry are explained. The standard period table is shown and also Janet's version of this. Chapter four has pictures of the basic particles like the proton, neutron and electron but also of another particle which we think is dark matter. Stable nuclides are investigated in the fifth chapter with a table of about 32 nuclides. Some semi-stable nuclides (those that decay with a longer half-life) are looked at also. Binding energy, a measure of how stable a particle is, finds an explanation in terms of stronger connections within the crystal. A preliminary table is given of the binding energies between the nucleons of various smaller atoms. Chapter seven, mathematical properties of the crystal, contains the reason why electron charges (and spin) interact via the surfaces of the atoms and particles. We prove the surface charge and spin theorems. Delta particles were

one of the reasons why the theory of quarks was invented. In latter part of chapter seven we explain how to describe them by putting positrons and electrons around the dark matter B particle. We also give a table of leptons (electrons and neutrinos and their heavy counterparts such as muons). Some of the formulas are more conjectural. Chapter eight shows that the crystal can be given a fractal structure by doubling the sizes of the fundamental particles, creating a double electron and so on. The Sierpinski triangle fractal is the plane version while the tetrix is the three-dimensional fractal that are both found in the crystal. Life depends upon various elements, especially carbon, oxygen and hydrogen. In chapter nine we interpret synthesis of three important isotopes of carbon in stars, in the earth's atmosphere or in nuclear reactors by equations and crystal diagrams. The final chapter ten investigates one of the heaviest elements to be found on earth, Bismuth. Its isotope Bi-209 is interesting for several reasons: it has a very large nuclear spin, is strongly diamagnetic and it is on the periphery of stability because it has so many protons (83) and neutrons (126). Any larger it would decay by splitting into lighter elements. The appendix contains a photograph of the wooden models that we built to visualise the atoms: proton (H-1), deuteron (H-2), Li-7, B-10, B-11, C-12, C-12 (Hoyle resonant state), F-22 (an unstable isotope of fluorine with a very high spin 4), Na-23 (a harder isotope to model in the crystal, with spin 3/2 and parity +1), and finally Bi-209. The element is actually made from 627 tetrahedra, each coloured red, black or yellow.

1.3 Example of a particle in the crystal

Boron-10 is a stable isotope of boron with a high nuclear spin 3. This isotope has 5 protons and 5 neutrons (i.e. 10 nuclides) in its nucleus and well as the 5 electrons

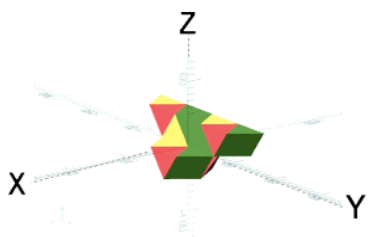


Figure 1.1 Boron-10 (B-10)
Spin 3 and Parity +1
Electron shells: 2,3
Formula is 0 1| 0 2 4

in its two shells. The parity of the nucleus is +1. This happens if there are 5 proton/neutron pairs (deuterons) in the nucleus. We normally assume that there are as many deuterons as possible in our models. Extra neutrons in isotopes are attached after the deuterons are fixed. The crystal model always assumes that each electron is associated with a proton which is made from three tetrahedra in the RBY configuration (in a left-handed orientation). The dark matter B acts like a glue to join the R and Y together.

We model B-10 in the crystal by first looking at the electron shells. The inner shell has two s electrons. This is interpreted in the crystal as a helium-4 (He-4) particle made from the union of two deuterons which contain this pair of two of electrons (of opposite spins). The model of He-4 is seen in the lower horizontal layer in Fig. 1.1. The two deuterons are joined side-by-side in their YR tubes of opposite spin in the y (time) direction. Thus this lower layer contains 12 tetrahedra, 4 of each colour R, B, Y, but they are joined into 2 protons and 2 neutrons, where each proton or neutron is a RBY tetrahedron triple. The difference between a proton and neutron is always just a rotation by 90 degrees so that the RY rhombus faces point up or sideways according to type of particle.

The second layer of the atom must have three deuterons containing the three p electrons in the second shell. The only way to obtain spin 3 is by putting these three deuterons into the same YR tube, so that their 3 protons and 3 neutrons all have the same spin (either all ½ or all -1/2). To obtain stability (compactness in the crystal) we join the 3 deuterons of the second shell layer together by rotating by 180 degrees at each join. Look at the upper layer in the crystal model of B-10 in Fig. 1.1.

Note that instead of putting the colours R, B, Y on the individual component tetrahedra of neutrons we have coloured the whole of the neutrons green so that one can see where they are situated.

Another property to see in the model is Hund's rule. This says that electrons in the outer shell should be as unpaired as possible so that their spins are the same. In this model of B-10 we see that the three electrons in second shell indeed have the same spin and are unpaired. However, a difference with the usual physics model is that one of the deuterons is in the s subshell (orbital), and the other two are in the p subshell. However, there is the possibility for electrons attached to a proton to move to that this is not a major problem for the model.

The formula 0 1 | 0 2 4 in Fig. 1.1 denotes the placement of the nucleons in the crystal. The 0 1 represent the first two deuterons in positions 0 and 1 (which is the complete s subshell. The second 0 2 4 denote the remaining three deuterons: 0 is in the 2s orbital and the 2 and 4 are in the 2p orbital of the second shell. The spin of a deuteron ± 1 is given in the numbering system by its number. Since 0 2 4 are all even they have the same spin whereas the 0 1 of the first shell cancel out to give spin 0. This shows us immediately that the spin of the model is 3.

Chapter 2 The Crystal

Only one thing exists, which is timeless, uniform, and unchanging. *(Parmenides)*

2.1 Why this?

In physics there are various alternatives to the standard model, which try to explain everything in an improved way. Notably there are the preon models [15]. The crystal model is not a preon model since it doesn't describe quarks or possible constituents of them. A major drawback to the standard model is the way that dark matter is omitted. This is not a surprise since we know that dark matter exists but cannot be directly observed (at present): it can only be inferred. This is similar to quarks. Quarks in the standard model cannot be observed individually, but in the standard model hadrons (protons, neutrons, pions etc) are all described by them.

The crystal theory tackles this quandary about dark matter head-on and starts out with tetrahedra of three colours, red, yellow and black: positive charge, negative charge and neutral dark respectively. First, we find out where these tetrahedra are situated.

There is a certain crystal. It is based on the body-centred cubic lattice (BCC) in Euclidean 3-d space. This is a well-known crystal with many elements and compounds taking this form. Essentially, it is the union of two cubic lattices, call them C_1 and C_2. Then $C_1 = (2Z)^3$, with coordinates (a,b,c) the ordered triples of even integers, and $C_2 = (2Z)^3 + (1,1,1)$, with coordinates (a,b,c) of all odd integers. From this basic lattice we find (coloured) tetrahedra which pack (or "space-fill") 3-d space, and from these tetrahedra we can find our models of atoms and particles.

2.2 Basic properties of the crystal and tetrahedra

The BCC lattice and its related tetrahedral honeycomb

We first explain how the crystal is formed from a certain lattice in Euclidean 3-space. It starts with a body-centred cubic lattice BCC. This is the union of two cubic lattices C_1 and C_2. Through every vertex of a cubic lattice there are three "lines" that are orthogonal to each other. A vertex of C_2 is the central point of a primary cube of C_1 and vice-versa. Each vertex of C_1 is on three infinite lines in the three orthogonal directions of the lines which are the same for C_2. Each tetrahedron has one "long" edge of length 2 on a line of C_1 and one long edge also of length 2 on a line of C_2. The other four edges of a fundamental tetrahedron have length $\sqrt{3}$ and are called "short" edges. The four faces of a tetrahedron are all the same: an isosceles triangle with one long side (edge) and two short sides (edges). The short edges go from a vertex of C_1 to one of eight nearest vertices in C_2. With an infinite number of these tetrahedra we can stick them together at common faces to obtain a unique "honeycomb" that fills 3-dimensional space, but this is the same as starting out with the BCC lattice and constructing the honeycomb from that.

Coloring the tetrahedra

We can say later precisely how the colouring is produced. First, here are the important properties to understand. The colouring of the tetrahedra in the honeycomb into three colours R, B, Y is actually unique up to symmetries of the tetrahedral honeycomb, once we choose to colour one tetrahedron red (R) and then an adjacent tetrahedron another colour, say black (B). Thus there are six different ways to colour the honeycomb because there are 6 permutations of R, B and Y. However, once we colour it, we assume the colouring is fixed, and this is our "crystal".

Thus the tetrahedra are coloured either Y, B or R which denote yellow, black, red. The colouring is made so that two tetrahedra with common face have different colours. There 24 tetrahedra passing through each vertex of the BCC lattice, 8 of each colour. A long edge is on four tetrahedra of two different colours. The long edges on a certain line of C_1 are all on four tetrahedra of the same two colours e.g. R, Y and they alternate RYRY going around the edge. A short edge is on 6 tetrahedra, two of each colour, which alternate RBYRBY or RYBRYB going around the edge depending upon the orientation. A line of C_2 in this same direction will have long edges with the same pair of colours. This coloured honeycomb of tetrahedra is called the "crystal".

The tubes of the crystal

If one direction of the possible three directions of the cubic lattices is fixed, then a collection of equally spaced parallel lines is obtained and an orthogonal plane section of these lines will be a square planar lattice of side length $\sqrt{2}$. The four parallel lines corresponding to a fundamental square of area 2 of this planar lattice bound an infinite tube with that square cross-section. There are three kinds of tubes RY, RB or YB depending on the three directions. (Later we shall call the RY direct the "time" direction and it will be the y axis in x,y,z coordinate system.) The outside faces of an RY tube have all R or Y faces (isosceles triangles) and no black faces.

The construction of fundamental tetrahedrons from a tube

One can take an RY tube, rotate it lengthwise so that one line is at the top, then slice it vertically at 45 degrees backwards and forwards to obtain concrete models composed of tetrahedra. (This was done to obtain our wooden models.)

How to construct physics particles

Here we present an overview of the construction process.

Protons and neutrons

The protons and neutrons plus their antiparticles have three connected tetrahedra, one of each colour, and they are related by a rotation. We have the formula RBY for them since the B always lies between the R and the Y with common faces to them, but the R and the Y are only connected by a short edge which is also common with the B.

The Deuteron

This is very important particle because it will be the basis for constructing the atoms. One way to construct it is to use an RY tube. Recall that this tube has a square cross-section and can be constructed by taking parallel lines in the BCC lattice. The deuteron is the union of a proton and neutron and therefore has 6 tetrahedra, two of each colour R, B, Y. It can be obtained using just two vertical slices (one forward and one backward at an appropriate distance, both orthogonal to the parallel lines, and at 45 degrees) of an RY tube that has already been rotated by 45 degrees in the line direction.

Slicing the deuteron into a proton/neutron pair, or into an anti-proton/anti-neutron pair.

It takes one more vertical slice through the centre of a deuteron to obtain the division into a proton and a neutron. First we rotate the deuteron by 90 degrees about the "line" direction. If the slice through the deuteron is taken forwards instead of backwards (or vice-versa) the deuteron appears to be the union of an antiproton and antineutron but then the deuteron would be called an anti-deuteron instead.

The parity of nucleons interpreted in the crystal

Inside a YR tube the deuterons (a proton/neutron pair) connect together alternately up or down by a 180 degree rotation about the direction of the tube. Later we investigate the "parity" ± 1 of single protons and neutrons (called "nucleons") within an atom. This is a multiplicative quantum property so that the parity of a particle is the product of the parities of its constituents. The rotation about 180 degrees corresponds to reversing the parity of such a nucleon. Since both nucleons reverse parity at the same time if the whole deuteron is inverted then the deuteron's parity is always considered to be +1. The parity property appears to be related to going into or out from the atom since these directions are reversed when the deuterons are flipped upside down. More details are given later.

The determination of "left-handed" particles such as a proton or neutron

The forwards/ backwards alternative means that there is a chirality (or mirror symmetry) property of the crystal. We assume that the basic particles (such as protons and neutrons) are always related to each-other by a rotation and not a reflection (which would give the anti-particles). This means that one of the main problems with the standard model (the lack of symmetry in handedness) is circumvented by assuming that the crystal starts out "left-handed" and that all the protons and neutrons that we have the same "handedness", i.e. left-handed.

A possible explanation for how such a crystal could form

This basic handedness could be explained by having the crystal coming from some cooling process subject to a rotational force acting on the basic forms (tetrahedra). Perhaps it is even possible to create these precise crystals using known materials. Conjecturally, it might happen in a neutron star, due to intense spinning and condensing.

2.3 Connection graph

Once we have the crystal and the associated 3-colouring of the tetrahedra there is a regular 4-valent graph G, a collection of vertices with edges which are ordered pairs of vertices and with 4 edges at every vertex. This graph induces various physical properties and especially the spin of any particle or atom that is made from the tetrahedra.

Definition of the connection graph and its 3-colouring

Let each tetrahedron in the crystal be a vertex of the connection graph G. Join any pair of tetrahedra in G whenever they have a common face. This is called a "quartic" graph, because there are four vertices adjacent to any vertex of G. An edge of G thus corresponds to any one of these faces between two adjoining tetrahedra. Colour the vertex of G with the same colour as the tetrahedron in the crystal. We see that no two vertices of the same colour in G have a common edge. This is called a "3-colouring" of G.

G is a bipartite graph

Definition: if the vertices of any bipartite graph can be partitioned into two disjoint subsets such that all the edges go between the two subsets but not inside each of the subsets then the graph is called "bipartite".

This property of a graph is equivalent to the property that every cycle (a path in the graph coming back to the same place) has even length. It turns out that G is bipartite. We give some reasoning for this later but one method depends on the orientation of the tetrahedra. There are two basic ways to number 0, 1, 2, 3 the four vertices of a tetrahedron in 3-d space so that they are not connected by a rotation of space, but only by a reflection. The crystal actually has a numbering

of its vertices, so that each fundamental tetrahedron has all four numbers on its vertices.

The spin of a tetrahedron and of particles

Since the graph G is bipartite its vertices (tetrahedra) can be divided into two parts. Let any tetrahedron from the first part have spin ½ and let the other tetrahedra be said to have spin -½. Since spin (in quantum physics) is additive, we define the spin of any particle made from tetrahedra to be the sum of the tetrahedral spins.

The spins within tubes

Recall that a tube is an infinite part of the crystal with square cross-section of area 2 bounded by 4 parallel lines of the BCC. The subgraph of G corresponding to an RY tube consists of an infinite number of 4-cycles $B<^{R}_{R}>B$ and $B<^{Y}_{Y}>B$ linked at common B's with Y and R alternating. Then all the R's and Y's in a tube have the same spin while the B's have the opposite spin. It is similar for RB tubes and YB tubes with the colours interchanged. Recall that spin is independent of colour, but related to the fact that G is bipartite.

Spins of tubes

There are two kinds of YR tubes: those where the R's or Y's have positive spin and those where they have negative spin.

Layers in the crystal

By placing YR tubes (think of long pieces of wood with square cross-section) of alternating spins side-by-side they form a layer. There are two ways (horizonal or vertical) of forming such a layer but they are equivalent.

Shells in the crystal model

Inside the crystal the shells of an atom form inside the horizontal YR layers. The outside shell in physics is the one directly visible by electromagnetic radiation. We will go into more details later.

Time and electro-magnetism related to coordinates (x,y,z)

We briefly state how we interpret physical properties in the crystal. Firstly, the YR tubes go in the" time direction". Thus time goes within a horizontal layer such as a shell. Time is the y direction when we use (x,y,z) coordinates. The vertical direction z (orthogonal to y) corresponds to the direction into (down) or out (up) from the atom. Later we refer to this as the "energy direction" (mainly because going to higher shells increases the energy level). The other direction x, orthogonal to both y and z is called the "magnetic direction", mainly because (magnetic) quantum spins alternate when going in that way.

2.4 Layer represented by hexagonal graph

A way of looking at the connection graph of a layer (or atomic shell) is to consider a planar hexagonal graph with a kind of 3-colouring (Fig. 2.1).

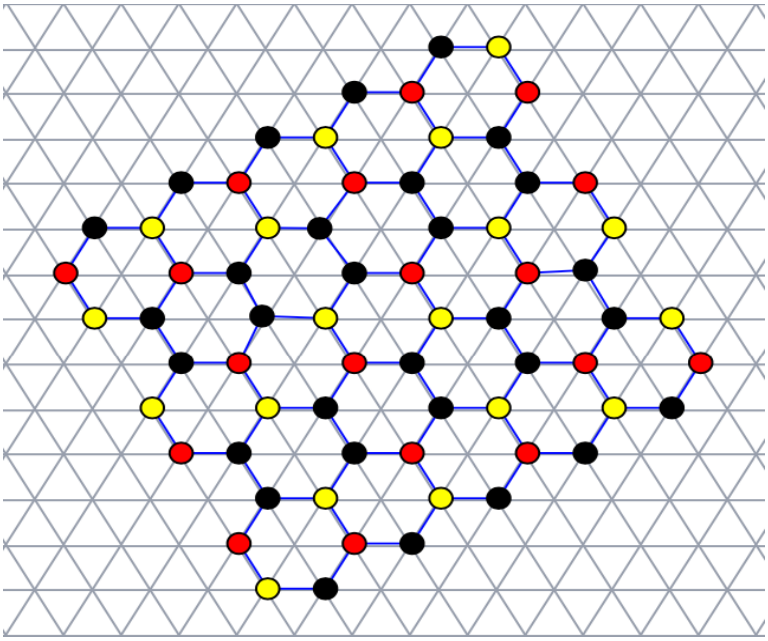


Figure 2.1. Hexagonal plane lattice corresponding to a RY layer

The red and yellow vertices correspond to single tetrahedra in G, but the black vertices of this hexagonal graph are in 2-1 correspondence with black tetrahedra in G. Joined black vertices merge into a single vertex in the G graph. This way we observe the square and hexagonal circuits in G. Recall that squares circuits in G correspond to 4 tetrahedra of 2 colours passing through a common long edge, while the 6 tetrahedra in a hexagonal cycle pass through common short edge and comprise all 3 colours. The YR tubes in this structure correspond to chains of squares linked at common black vertices. Each of these squares has alternately 2 R's and 2 Y's. A YR tube links to the next YR tube though Y-R links. In Fig. 2.1 all tubes go in a SW-NE direction.

Chapter 3 Crystal Theory

So let's look at the bird and see what it's doing — that's what counts. I learned very early the difference between knowing the name of something and knowing something. *(Feynman)*

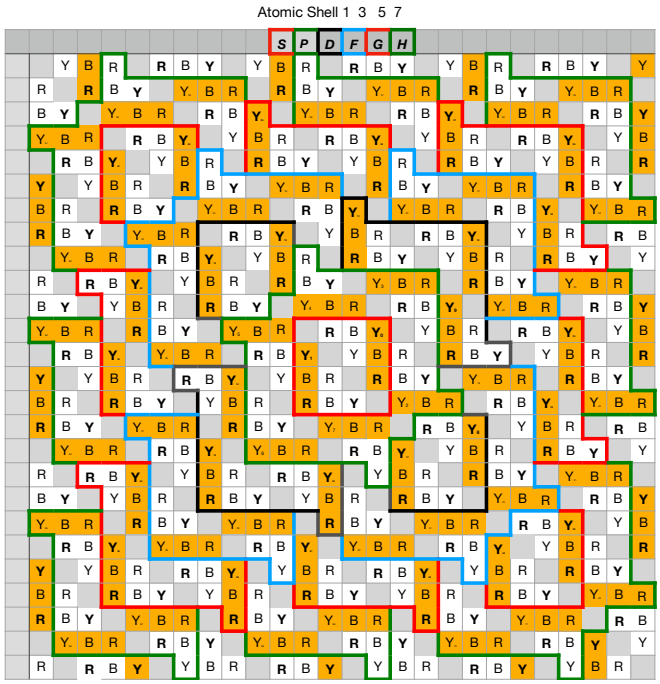


Figure 3.1. ODD SHELL

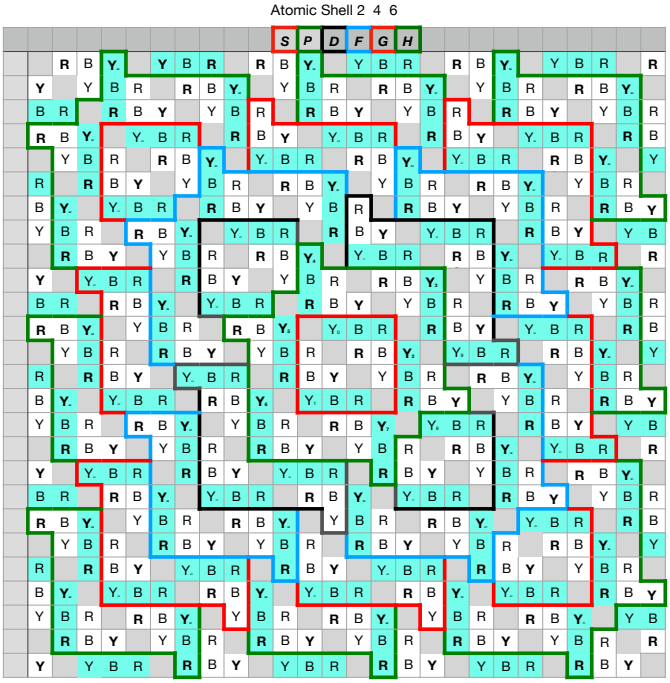


Figure 3.2. EVEN SHELL

3.1 Types of atomic graph paper

To describe the 3-dimensional crystal in an efficient way we use two kinds of atomic graph paper.

1. Atomic graph paper AGP1 (see Fig. 3.1) represents odd shells in the crystal.
2. Atomic graph paper AGP2 (see Fig. 3.2) introduces us to even shells in the crystal.
3. Each shell layer is represented by an atomic graph paper.

4. The YR-tubes that comprise the shell layer are seen in the APG running top left to bottom right and are separated by blank squares (which are not particles).
5. The “spin” of a tube is the spin of any Y (electron) or R (positron) in it.
6. Any dark matter B in a tube has the opposite spin to its tube.
7. The spin of a tube alternates + or – as we go from bottom left to top right.
8. The spin of any particle made up of R’s, Y’s and B’s is the sum of the spins of its constituents.
9. The spin of a proton BR includes its corresponding electron Y.
10. The atoms are made from layers of shells, starting at the bottom innermost shell with AGP1.
11. In the AGP we see the details of the subshells or orbitals.
12. The s, p, d, f, g, h subshells are bounded on the outside by red, green, black, blue, red, black lines respectively on the AGP.
13. The number of deuterons in each subshell is 2, 6, 10, 14, 18, 22 respectively.
14. The parity of the subshells alternates ±1 going from the innermost s subshell of parity 1 to the outer subshells such as f with parity -1.
15. The parity is independent of the layer or graph paper AGP1 or AGP2.
16. We assume that the electronic structure of the atom transfers over in the main to the nucleus.
17. Thus in general, if an atom such as carbon-12 has two electron shells then we use two graph papers AGP1 and AGP2.
18. There is a shell theory for the nucleus with “magic numbers” and so on, but the geometry and shells for the nucleus here are different.
19. The standard filling of electron shells and orbitals (low energy to higher energy) from chemistry is according to 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p : this is followed in the crystal model, except possibly at the top shells where small differences can occur.

20. This is explained by the fact that top shell electrons are mobile and while the nucleus doesn't move, the electrons there, Y's attached to BR's in protons, may move to the desired position (of perhaps smaller energy).
21. However, there are some exceptions to the above filling rule due to the closeness of energy levels with many of the consecutive subshells and in some elements the placement is contested by chemists and physicists.
22. In general, the energy levels of all electrons in a certain shell (layer) are very close.
23. When building up the layers the AGP's are centred according to the s subshell (the red subsquare) and the higher shell AGP is put on top of the lower.
24. The vertical connections between the two layers are produced by a bold R below and a light Y above, or by a bold Y below and a light R above.
25. Note that the "dark matter" B's only connect in the same layer.
26. The protons are straight triples YBR.
27. Bent triples RBY are neutrons.
28. All protons of the same parity in the same shell look the same in the APG.
29. Given a BR in a proton or neutron, there is only one way to complete it to a YBR proton or neutron by adding a connecting Y to the B.
30. This is due to the left-handness rule: the other way of completion would give a right-handed particle which is not used in the model.
31. Similarly, adding an R to the B of a YB yields a unique left-handed particle. Adding in the alternate way yields the right-handed antiparticle.

3.2 Connections in the crystal

Any tetrahedron coloured Y, B or R in the crystal has four triangular faces. These can connect with four other tetrahedra two of each colour that is not the same as the original colour. E.g. Y connects with 2 B's and 2 R's.

Rules of connection in the graph paper.

On a single graph paper (same shell):

1. Horizontal connection between Y and B or R and B.
2. Diagonal connection Y connecting to R in different tubes.
3. Vertical connection between Y and B or R and B.

See Fig. 3.3 below.

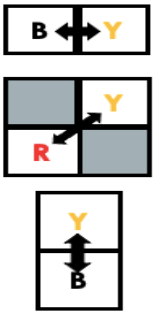


Fig. 3.3 Three kinds of connections within an AGP

Between two AGP's (consecutive shells, "rule of boldness"):

1. **R** in AGPi connects to the Y in AGP(i+1) directly above it.
2. **Y** in AGPi connects to the R in AGP(i+1) directly above it.
3. There are no B connections between consecutive shells.

3.3 Crystal symmetries (induced from BCC lattice)

Here we summarize some of the relationships in the crystal between particles. The crystal has an automorphism group which is a subgroup of the group of the BCC lattice. This latter group is generated by translations, rotations and reflections. Thus the subgroup fixing the crystal will also preserve the three colours R, B, Y of the fundamental tetrahedra. Hence it is a normal subgroup H of index 6 in the full BCC group. This means that every left coset xH is the same as the right coset Hx and also that there are 6 cosets xH which form a partition of the group. For each of the 3! = 6 permutations of R, B, Y there is a corresponding

coset. We do not aim to list all the details of these groups of symmetries here but summarize them.

1. Translations (permute protons and permute neutrons)
2. Rotations (weak force, neutrinos):
    a. proton ↔ neutron by a certain 180 degree rotation
    b. Charged pion ↔ muon by a similar 180 degree rotation
3. Reflections (particles to anti-particles if also R ↔ Y)
    a. proton (LH) ↔ anti-proton (RH)
    b. neutron (LH) ↔ anti-neutron (RH)
4. Colour Asymmetry gives Particles/Space
    a. B (dark matter binds Neutron RBY)
    b. Y splits from RB to give Proton
    c. RY give photons which mediate between us and space.
    d. When a particle and anti-particle join they give photons (plus dark matter).
    e. There appear to be two kinds of basic dark matter: B which is at the centre of protons, and the antiparticle $\overline{B}$ at the centre of neutrons.
    f. Since B and $\overline{B}$ never join and also are not related to R and Y they do not annihilate into photons and are in practice “invisible”.
    g. These B’s can be positive or negative spin depending on the R-Y tube.
5. Reasoning behind hierarchy R-B > Y-B > R-Y
    a. Dark matter gives most mass but hides between R and Y inside the R-Y tubes and not on the surface of the tubes.
    b. Protons RB are ubiquitous but not antiprotons YB, and this implies that the binding strength R-B is stronger than Y-B.

c. R-Y is electromagnetism (weaker than strong force inside particles such as RB).
d. In the crystal the vertical direction R-Y is considered to be the electric force, but orthogonal to the horizontal direction where the R-Y connections are considered to be the magnetic force.
e. The spin oscillates in the horizontal layer with every change of tube.

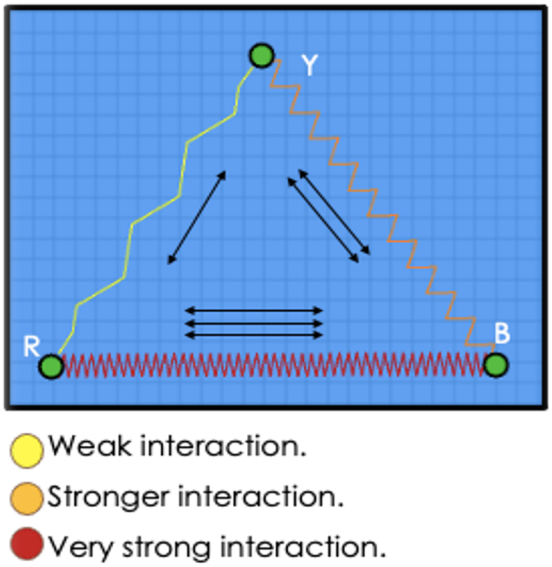


Fig. 3.4 Hierarchy of connections

3.4 Crystal Coordinates (Time, Energy, Magnetic)

The crystal coordinate system is related to the three orthogonal directions of the BCC lattice by rotation by 45 degrees about the b or y axis. It is basically a transformation (x,y,z) = ((a-c)/2, b/2, (a+c)/2), where a,b,c are the three directions of the BCC.

1. x corresponds to magnetism (spin)
2. y corresponds to time (forward with positive y)
3. z corresponds to energy (increasing with shell numbers 1, 2,…)
4. Up with z corresponds to more energy (orbitals in same shell have (almost) the same energy)

5. Reflection in the x– z plane reverses time $y \leftrightarrow -y$ and takes particles to anti-particles by changing orientation and switching colours R and Y.

Now we explain in more detail how the crystal relates to the physics and chemistry of the atoms.

3.5 Atomic Shells

We summarize what the shells are in the crystal.

- The top (outer) shell with highest value of z is the connection with the real world.
- An atomic shell corresponds to a horizontal layer in the crystal. Let i be some integer which can be suitably chosen, raising or lowering the atom.
    - Shell 1: z in $[i-1, i]$, principal quantum number 1
    - Shell 2: z in $[i, i+1]$, principal quantum number 2
    - Shell 3: z in $[i+1, i+2]$, principal quantum number 3
    - Shell k: z in $[i+k-2, i+k-1]$ (outermost shell)
- In our computer models i is usually 0 so that the bottom (innermost) shells line up,
- If there are multiple atoms we assume that the top shells of the atoms are at equal heights. This makes the "real world" a horizontal layer and the particles appear to be "floating" just below this flat surface.
- In any case, changing the value of i doesn't change the model.
- The principal quantum number of shell k is k.
- Each atomic graph paper represents a shell.
- There are two kinds (odd and even shells).
- The lower shells are (electromagnetically) not directly visible to the real world.
- This leads to things like quantum teleportation and entanglement because many other interactions occur below the real world level and directly connect up the interiors of atoms without going through the top sheet.

- See Fig. 3.5 for a diagram of an atom represented as a sphere floating in an ocean with the top layer the real world sheet ($z = k$). The shells are actually made from subshells and these have various names, s, p, d, f depending on their sizes.

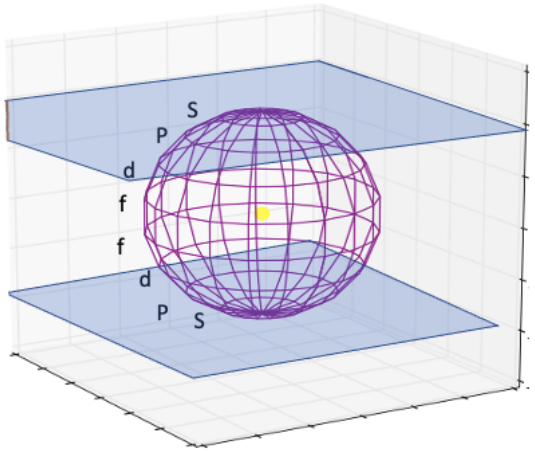


Fig.3.5 An atom in the crystal with various shells and subshells

3.6 Right-handed particles

An example of a right- handed particle is an anti-proton (RBY) which is a positron R and electron Y with dark matter B between them. This kind of particle comes by reflection or mirror symmetry from a left-handed particle. The following Table 3.6 indicates particles and their antiparticles.

Particle	Antiparticle
Electron(Y)	Positron(R)
Positron(R)	Electron(Y)
Time	– Time
Dark matter(B)	Dark matter(B)
Charge	– Charge
Spin	– Spin
Parity	– Parity
Left-handed	Right-handed
Right-handed	Left-handed

Table 3.6 Particles/Antiparticles

Note that properties like spin derive from a basic property of the crystal, that the tetrahedra come in two kinds, and the face-connection graph of these tetrahedra is bipartite. This means that once we know where the particle is positioned in the crystal we know its spin precisely, because it is the sum of the tetrahedral spins.

When we say "spin i" (e.g. of an element) often we actually mean "maximum absolute value spin i", which is the interpretation accepted in quantum mechanics because in a measurement it could turn out to be one of -|i|, …, |i| in integer increments.

3.7 Tetrahedral spin

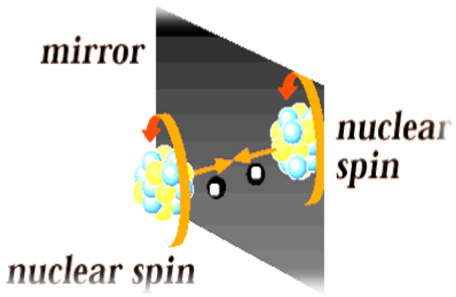


Fig. 3.7 Illustration of a mirror reflection changing spin.

- Labelled tetrahedra can be reflected in a mirror; see Fig. 3.7.
- This changes the spin between $+1/2$ and $-1/2$.
- Two tetrahedra that adjoin at a triangular face have opposite spins.
- A baryon (proton or neutron) is comprised from a Y joined to a B joined to an R. This means that both the Y and R in the proton have the same spins while the B between them has the opposite spin. The total resulting spin of these baryons is then ± ½.
- (Coloured) Particles (LH) change to anti-particles (RH) when they are reflected.
- Then the R and Y are flipped, while B stays the same.
- Time (which is the y axis in the crystal coordinate system) will also usually change direction as y changes to -y.

3.8 Parity of atoms/electrons in the crystal

It is a property of particles in the standard model that they have a certain parity. This is basically the shape of their wave function, whether it is symmetric (even function) or anti-symmetric (odd function) with respect to the normal Euclidean (real world) coordinates. By this we mean that the wave function f satisfies $f(v) = f(-v)$ or $f(v) = -f(-v)$, in the coordinates v. Parity is either ± 1, and is multiplicative, in that if a particle is made up of sub-particles with certain parities then the parity of the larger particle is the product of the parities of the smaller ones.

One can measure the parities of electrons or of nuclides separately but in the crystal model these parities are related to each-other. Here we explain how this is accomplished. The parity of electrons is something that is invariant with different electron shells but depends only on the subshells (orbitals). The subshell (orbital) s (innermost) has parity $+1$, the next subshell (orbital) p has parity -1, the next one d has parity 1, the f subshell has parity -1, and so on it alternates with successive subshells. We assume that the parity of a proton or neutron or electron positioned in the corresponding part of the crystal inherits its parity from the corresponding position.

In the AGP's (AGP1 and AGP2) we indicate the subshells by coloured lines; see Fig. 3.8. We start with the central red box, which is the s subshell of parity +1. Going out from this there is the green subshell p of parity -1. Then there is the black subshell of parity +1, and so on. Notice that the subshells start to break into pieces as they go out.

An interesting observation is that the difference between a proton of parity +1 and a proton of parity −1 in a certain shell (a fixed AGP) is that they are related by a 180 degree rotation in the crystal: they "face" either up or down in the z direction. The "free" electrons with different parities attached to these protons also point in opposite z-directions and so their parities make sense as they are induced by the proton parities.

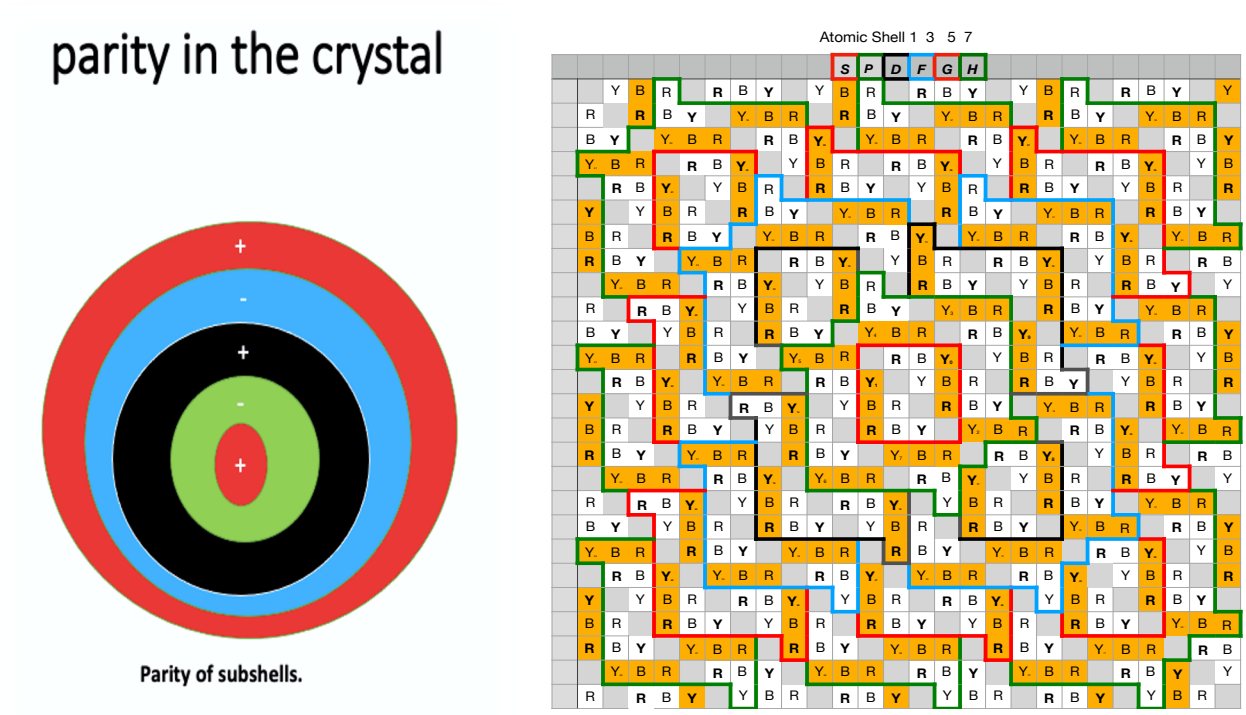


Fig. 3.8 The AGP (here AGP 1) represents the orbitals which determine parities of particles

3.9 Quantum numbers explained by the crystal

- Principal quantum number (n).
  - Atomic Graph Paper AGP1 for odd shells
  - Atomic Graph Paper AGP2 for even shells
- Orbital angular momentum quantum number (l). (subshell)
  - s (inner-most, zero angular momentum) parity +1, (topologically a sphere in crystal). Symmetric wave function, parity $+1$.

- p (next one out, parity -1), (topologically a torus), anti-symmetric wave function, parity -1.
- d (further out) parity +1 (breaks into 4 pieces in crystal), symmetric wave function, parity +1.
- f, g, h, … (break into even more pieces).

♦ Electron spin quantum number (M_s). (±1/2 for electrons).

♦ Electrons (always associated with protons in the crystal) are paired, and the natural way in the crystal is to first pair the protons on opposite sides of the central point in the middle of the red box, and then to pair their electrons (of opposite spin).

♦ This explains the Pauli exclusion principle, that two electrons with the same four quantum numbers in an atom do not exist.

3.10 Janet's periodic table

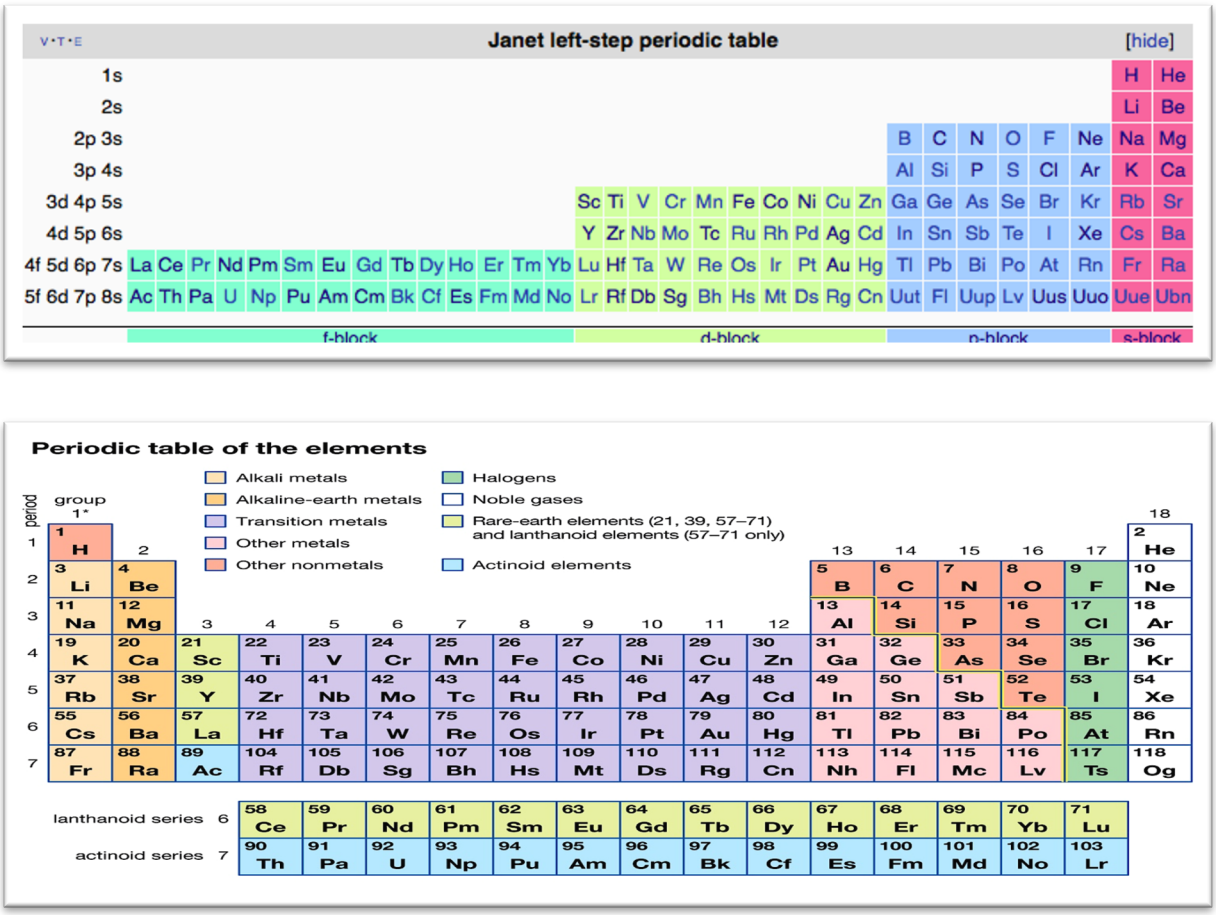


Fig.3.9 Janet's left-step and standard periodic tables

Janet’s left-step periodic table shows the filling of electron shells compared with the standard periodic table. Note that for some elements there is dispute in the precise placement; see Fig. 3.9.

The crystal theory works with Janet’s periodic table better than the usual periodic table of the elements. This is because the crystal theory starts with the filling of the electron shells as in Janet’s (left-step) periodic table and doesn't deal immediately with the chemical properties. The crystal method of building the atoms follows Janet’s method closely with the atomic nuclides built from bottom up starting subshell s, the He-4 atom or alpha particle nuclide when filled. Janet’s periodic table goes from the left to right, that means it starts from hydrogen then helium and so on.

Chapter 4 Particles

It strikes me that all our knowledge about the structure of our Earth is very much like what an old hen would know of the hundred-acre field in a corner of which she is scratching. (*Charles Darwin)*

4.1 Basic Particles

Using the computer program *OpenScad* we draw some smaller particles in the crystal. Recall that the horizontal layers in the x-y plane are the shells with x being magnetic and y being time. Up with z means higher (mainly electric) energy. We also have wooden models of many of these particles that are made from sawing long pieces of wood and gluing. See the Appendix.

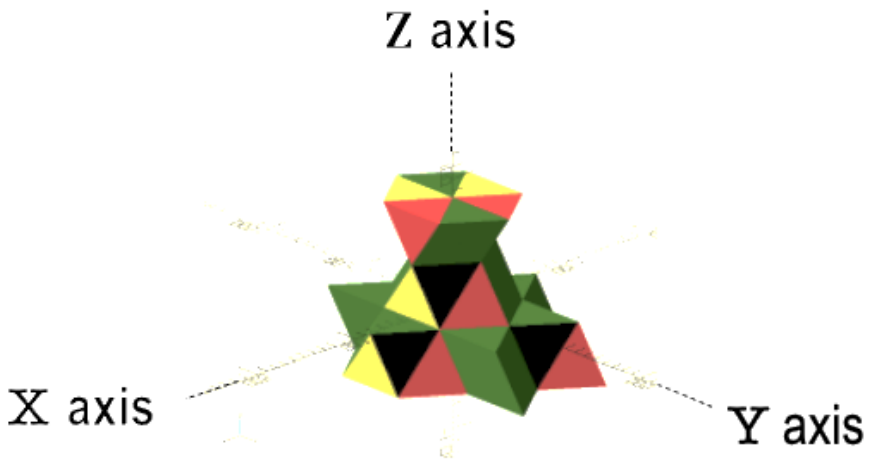


Fig. 4.1 A sample (not real) particle with 3 shells

In Fig. 4.1, as in many of the following diagrams, the neutrons are indicated in green and the protons are left in the RBY colours.

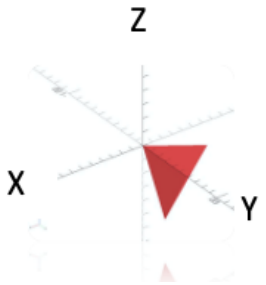


Figure 4.2 positron (R)

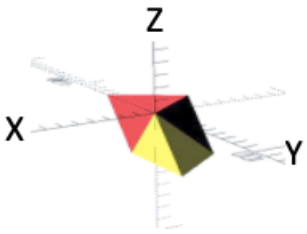


Figure 4.3 neutron (RBY Formula is 0b

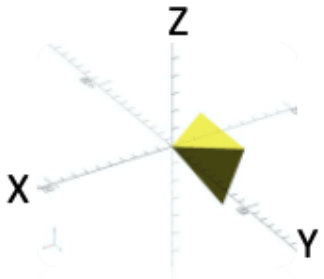


Figure 4.4 muon (YB)

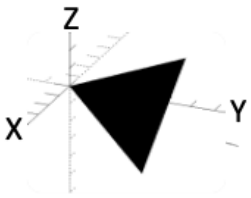


Figure 4.5 dark matter (B)

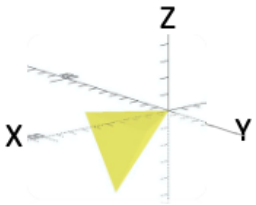


Figure 4.6 electron (Y)

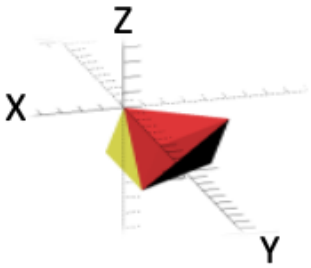


Figure 4.7. Right-handed anti-neutron (RBY) (RY's are pointing sideways)**Formula is 0b**

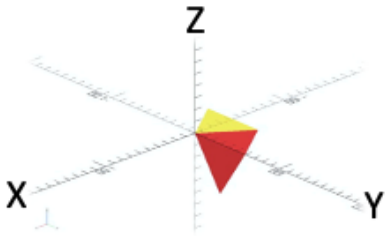


Figure 4.8 left-handed proton particle (RBY) (RY's are pointing up which indicates a proton) **Formula is 0a**

Here we summarize some of the basic particles with a short description of their properties.

Figure 4.2 POSITRON (R)

The positron or positive electron is the antiparticle or the antimatter counterpart of the electron. In addition, the positron has an electric charge of +1, spin of ±½ and it has the same (rest) mass as the electron which is $5.48579909070(16) \times 10^{-4}\ u$. Note that *u* is the atomic mass unit, the mass of Carbon-12 atom divided by 12. An alternate mass unit often used for particles is eV/c^2 (electron volt per speed of light squared) and KeV for a thousand, MeV for a million, or GeV for a billion election volt (per c^2): of course, Einstein's equation explaining the equivalence of mass and energy makes this conversion.

Figure 4.3 NEUTRON (RBY)

The neutron is the particle found most often in the atomic nucleus with a mass equal to almost 1 GeV (slightly more than 1u) and charge equals zero. Furthermore, the neutron has a spin equal $\pm$ ½ depending on which (RY)-tube it is in the crystal. If the neutron sits in an even tube, its spin will be $+$ ½ . In contrast if the neutron sits in an odd tube its spin will be $-$ ½ . Additionally, we sometimes give the neutrons a green colour when we fancy to see where the neutrons and protons are in a diagram.

Figure 4.4 MUON/ CHARGED NEGATIVE PION (YB)

The Muon is an elementary particle (lepton) similar to the electron Y in the spin and charge. Thus, the muon has charge negative one and spin $\pm$ ½ . However, the muon has more mass and should be associated with a dark matter B. Moreover, the muon is an unstable subatomic particle with a mean lifetime of $2.2\ \mu s$. The crystal formula is still being finalized. It is possible that there is an

associated neutrino (perhaps a surface triangle) that is attached to give the correct spin, because just a Y and B should have a spin of 0.

Figure 4.5 DARK MATTER (B)

Dark matter is hard to detect but we know it is there from effects such as the abnormal rotations of galaxies. We know how there is also a lot of dark energy affecting the universe's expansion. In the crystal dark matter avoids electromagnetic radiation which interacts via R/Y surfaces. The dark matter B has a spin ± ½ but no electrical charge. It is "hidden" inside the R/Y tubes which go in the time direction and so B is normally unobservable. However, B interacts on the outside surfaces of the R/B and Y/B tubes that have a limited time duration (going at 45 degrees up to the surface layer). Thus they affect the interior of atoms (like the "strong force" of the standard model). There appear to be at least 4 kinds of B's, depending on whether they are in a proton or neutron, and of positive or negative spin ± ½. They would also have an induced parity ±1 but it is not clear if this is meaningful.

Figure 4.6 ELECTRON (Y):

The electron Y in the crystal occupies fixed positions in contrast to the standard model and in chemistry where electrons move around with quantum amplitudes (kinds of complex number probabilities) expressed by wave functions that build the shells and orbitals around the nuclides. This does not mean that electrons can't take up different positions in the crystal. The electrons (especially those that are on the outside top of the crystal particles) can move to other nearby "proton RB positions". On the other hand it appears that the "neutron electrons" are fixed to their positions, being bound more strongly to the corresponding RB's. (Recall that in the atomic graph paper the protons are straight RBY's and the neutrons are the bent ones.) In reality though, the protons and neutrons are the same except for a rotation. Although we are thinking of the crystal as unchanging,

the particles can be thought of as bubbles that move through the crystal. In this way the electron bubble can switch between various positions adjacent to its associated proton and attach itself to other proton positions. In summary, the electron has a spin $\pm$ ½ , charge negative one and a mass of $5.48579909070(16) \times 10^{-4}$ u in the standard mass scale associated with carbon-12.

Figure 4.7 PROTON (RBY):

The Proton is one of the very few stable subatomic particles and has a positive charge +1 with spin equal $\pm$ ½ , and it has a mass 1.00728 u . In the atomic graph paper (AGP) they are the straight YBR's. In the crystal a proton has a unique RY surface rhombus made from two triangles of colours R and Y. This RY face turns either up or down in the crystal (in the "energy" z direction). This correlates with the electronic (charge) interaction through that direction. The corresponding Y in the proton can be mobile (in a "bubble") and be associated also with other "nearby" protons. However, the details of movement and other associated ideas still have to be worked out.

Figure 4.8 RIGHT-HANDED PARTICLES (e.g. RBY)

Right-handed particles are obtained from left-handed ones in the crystal by reflection. To make a true anti-particle also the roles of Y and R have to be reversed. Thus, there are anti-protons and anti-neutrons easily seen in the crystal. For example, we can say that an anti-proton in the AGP is a straight RBY with the (positron) R starting further to the top left. Perhaps this means that in the time direction (the y-axis, running top left to bottom right in the AGP) either the proton Y or the anti-proton R interacts first with other particles and becomes a possible free agent. Y and R are anti-particles of one-another but B is its own anti-particle. The definitions of "left" and "right" are basically dependent upon the actual

particles while some particles are not orientable and so are both left and right. Spin is another “chiral” property that is defined in the crystal with a handedness so that particles with a non-zero spin should have left- and right-handed types.

Chapter 5 Stable Nuclides

I would rather discover a single fact, even a small one, than debate the great issues at length without discovering anything at all. (*Galileo Galilei)*

Stable/semistable nuclides						
Atom	Atoms Symbol	Number of Protons	Number of Neutrons	Formula	Spin	Parity
Proton(H)	P	1	0	0a	1/2	+
Neutron (10.3m)	N	0	1	0b	1/2	+
Deuteron	D	1	1	0	1	+
Tritium (12.3y)	^{3}H	1	2	0 1b	1/2	+
Helium-3	He-3	2	1	0a 1 or 0| 0a	1/2	+
Helium-4	He-4	2	2	0 1	0	+
Lithium-6	Li-6	3	3	0 1| 0	1	+
Lithium -7	Li-7	3	4	0 1| 0 4b	3/2	-
Beryllium-7 (53d)	B-7	4	3	0 1| 0 2a	3/2	-
Beryllium-8	Be-8	4	4	0 1| 0 1	0	+
Beryllium-9	Be-9	4	5	0 1| 0 2 3b	3/2	-
Boron-10	B-10	5	5	0 1| 0 2 4	3	+
Boron-11	B-11	5	6	0 1| 0124b	3/2	-
Carbon-11 (20.4 min)	C-11	6	5	0 1| 015a7	3/2	-
Carbon-12	C-12	6	6	0 1| 012a34b	0	+
Hoyle state	C-12	6	6	0 1| 0123	0	+
Carbon-13	C-13	6	7	0 1| 0123b7	1/2	-
Carbon-14(5730y)	C-14	6	8	0 1| 01234b7b	0	+
Nitrogen-14	N-14	7	7	0 1| 01234	1	+
Nitrogen-15	N-15	7	8	0 1| 012347b	1/2	-
Oxygen-16	O-16	8	8	0 1| 012345	0	+
Oxygen-17	O-17	8	9	0 1| 0 1 2 3 4 8 12b	5/2	+
Oxygen-18	O-18	8	10	0 1| 0 1 2 3 5 6 9b 14b	0	+
Fluorine-19	F-19	9	10	0 1| 0 1 2 3 4 5 6 9b	1/2	+
Fluorine-22 (4.23s)	F-22	9	13	0 1| 0 1 2 3b 4 5b 6 7b 14 16 26b	4	+
Neon-20	Ne-20	10	10	0 1| 0 1 2 3 4 5 6 7	0	+
Neon-21	Ne-21	10	11	0 1| 01 2 3 4 5 7 13 12b	3/2	+
Neon-22	Ne-22	10	12	0 1| 0 1 2 3 4 5 6 7 12b 17b	0	+
Bismuth-209 (2.01 10^{19} y = ~ billion times age of universe)	Bi-209	83	126	0 1 2b 3b 5b 6b| 0 1 2 3 4 5 6 7 9b 10b 12b 14b 16b 17b| 0-17 18b 19b 20b 21b 22b 25b 26b 27b 28b 30b| 0-31 33b 35b 38b 40b 42b 44b 47b 49b | 0-17 18b 19b 0b 21b 23b 25b 26b 27b 28b 30b| 0 2 4 8 12 24b plus one of the four options 1b 17b, 3b 19b, 3b 23b or 19b 23b	9/2	-
Sodium-23	Na-23	11	12	0 1|0 1 2 3 4 5 6 7 8 12 b or 0 1| 0 1 2 3 4 5 6 7 17b| 0	3/2	+
Magnesium-24	Mg-24	12	12	0 1| 0 1 2 3 4 5 6 7 | 0 1	0	+
Magnesium-25	Mg-25	12	13	0 1|0 1 2 3 4 5 6 7|0 2 8b	5/2	+

Table 5.1 List of Particles in the crystal

5.1 Explanation of Table

In the previous table (Table 5.1) we have listed various smaller stable or semi-stable nuclides with a formula to describe their shape and position in the crystal. We also included Bismuth-209 as the largest remarkably stable known nuclide. An interesting fact about this element is that it was thought to be stable until 2003 CE. Then it was discovered to have a half-life that is something like a billion times the age of the present universe. Looking closely at our model we see that we give 4 alternative choices of nuclide isomers that possibly have different half-lives. There is clearly a most stable one, but others could also be very stable. We suspect that bismuth-209 has at least 2 or perhaps up to 4 closely related nuclear isomers and at least one is stable but the others slightly less so. Another interesting fact about bismuth is that it is one of most strongly diamagnetic elements (repelling magnetic lines of force). We shall later in Chapter 10 see how this is interpreted in the crystal.

We apply the crystal model to these elements starting from the known electronic configurations, progressing to the known spin and parities of the nuclides. There is a specific numbering system. First, we assume that the crystal is divided in a very particular way into proton and neutrons, with the protons and neutrons paired into deuterons. Then we add neutrons around the basic structure of deuterons so that the number of connections is maximised and the nuclide will be most stable.

There is a numbering system n = 0, 1, 2, … for the deuterons, going in an anticlockwise spiral starting from the middle s orbital (the red square which corresponds to deuterons 0, 1). For each AGP the numbering system is the same and the orbitals are: s = 0-1 (red box), p = 2-7 (red to green), d = 8-17 (green to black), f = 18-31 (black to blue), g = 32-49 (blue to red), h = 50-71 (red to green).

In this way we know the spin of any deuteron (±1), which is +1 if its number n is even, and –1 if n is odd.

Further, the proton of a deuteron with associated non-negative integer n is labelled na, while the neutron in that deuteron is labelled nb. The parity of any deuteron is +1, while the parity of a proton or neutron na or nb is –1 if n is in one the ranges 2-7, 18-31 or 50-71, and +1 otherwise. The spin of an na or nb is ½ if n is even, and – ½ if n is odd i.e. it is $(-1)^n$ ½. Since the spins and parities of nuclides have been experimentally found, this information leads often to small numbers of possible crystal models, and even unique (most stable) ones in most cases that we have investigated.

Some nuclides/atoms are more interesting to construct because of their more unusual properties. For example, boron-10 has a very large spin 3: it has 5 protons and 5 neutrons which should be in 5 deuterons: the electron shell configuration shows two deuterons from subshell s: these will take up positions 0 and 1 completely filling shell 1 and making essentially a helium nuclide: then we move to the second shell and add the three more deuterons in positions 0 2 4, which are in the same R/Y tube and therefore contribute all the spin 3. Thus, the crystal model is of B-10 is uniquely determined. The parity of B-10 is +1 since deuterons always have this parity and parity is multiplicative.

Why are there stable or semi-stable nuclides? Firstly, a nuclide might not be stable if it is close in its crystal form to another more stable nuclide. Stability should be determined mainly by the shape of the crystal, and if it is more rounded with more internal connections it is more stable. Decay of atomic nuclides in the crystal model can be explained in the data.

First example: the neutron decays to proton with a half-life of 10.3 minutes and for this to happen the neutron 0b changes to a proton 0a. There is a natural rotation in the crystal that achieves this quite simply. If the crystal were floating in an ocean with the top level being the outer shell, then this might explain the natural decay of a neutron into a proton, since the proton is "facing" to the top, it may have more buoyancy when it is oriented up. Thus, when a neutron (sideways-facing) is alone, it will naturally rotate so that it is facing upwards, and then it will become a proton. Of course, some protons face down, so that this argument may have to be modified. In the standard shell 1, the protons of parity +1 face up, while those of parity –1 face down. Hence, perhaps a "free" neutron of parity +1 changes always to a proton of the same parity +1. If an experiment is made with a wooden model of a neutron in water, actually the large R-Y face always turns so that it is orthogonal to the "magnetic" direction x.

Second example: tritium H-3 or T (a proton and two neutrons) 0 1b decays to helium-3 (two protons and a neutron) with half-life of 12.3y, which means the 1b neutron goes to a proton in helium-3. There appear to be two possibilities for He-3: one has less connections but stays in the first shell 0a 1 (or equivalently 0 1a), and the other has more connections but has a proton in the second shell 0 | 0a. This latter possibility is geometrically the same as the tritium above via a rotation.

Third example: beryllium-7 or Be-7 (4 protons and 3 neutrons) decays to lithium-7 (3 protons and 4 neutrons) with half-life of 53 days and this will happen when the 2a proton in beryllium-7 goes to the 4b neutron in lithium-7. In doing so the spin 3/2 and parity –1 are retained.

5.2 Pictures of stable or longer half-life nuclides

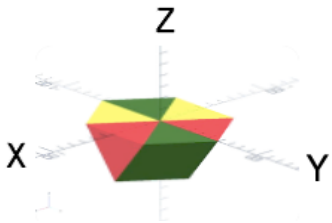


Figure 6.1. Helium-4 (He-4)
Spin 0 and Parity +1
Electron shell: 2
Formula is 0 1

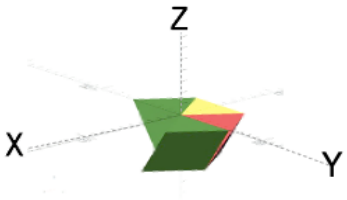


Figure 6.2. Tritium-3 H-3 (12.3y)
Spin 1/2 and Parity +1
Electron shells: 2,1
Formula is 0 1b

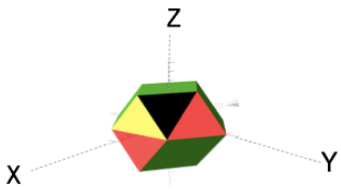


Figure 6.3. Beryllium-8 Be-8 (8.19×10^{-17} s)
Spin 0 and Parity +1
Electron shells: 2,2
Formula is 0 1| 0 1

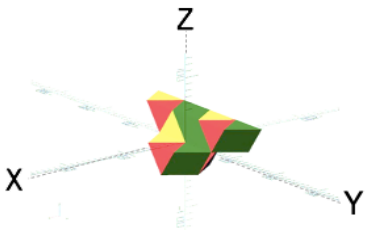


Figure 6.4 Boron-10 (B-10)
Spin 3 and Parity +1
Electron shells: 2,3
Formula is 0 1| 0 2 4

Figure 6.5. Lithium-7 (Li-7)
Spin 3/2 and Parity −1
Electron shells: 2,1
Formula is 01 | 04b
On the left-hand side the model is upside down

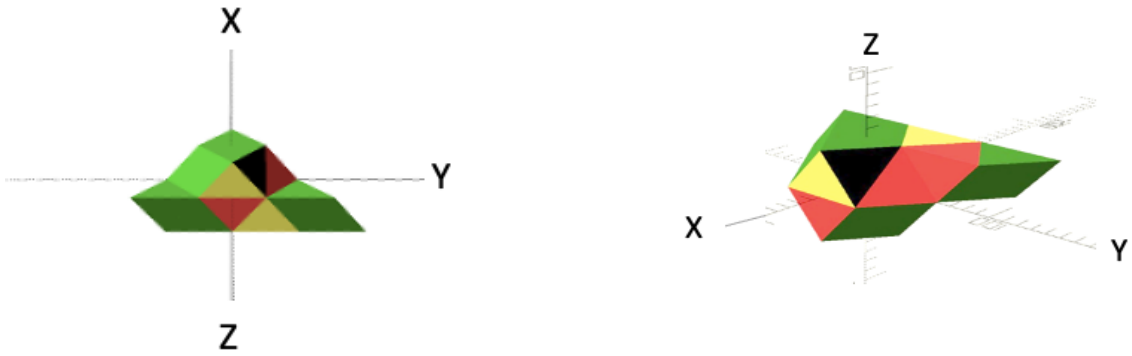


Figure 6.6 Boron-11 (B-11)
Spin 3/2 and Parity −1
Electron shells: 2,3
Formula is 01| 0124b
On the left-hand side the model is upside down

Figure 6.7. Fluorine-22 (F-22)
Spin 4 and Parity +1
Electron shells: 2,7
Formula is 01| 0 1 2 3b 4 5b 6 7b 14 16 26b
On the left-hand side the model is upside down

Figure 6.8 Sodium-23 (Na-23)
Spin 3/2 and Parity +1
Electron shells: 2,8,1
Formula is 0 1| 0 1 2 3 4 5 6 7 17b|0
On the left-hand side the model is upside down

Chapter 6 Binding energy

I have often made the hypothesis that ultimately physics will not require a mathematical statement, that in the end the machinery will all be revealed, and the laws will turn out to be simple, like a chequer board with all its apparent complexities. *(Richard Feynman)*

6.1 Calculation of binding energy

We calculated the binding energy of smaller nuclides (in atomic mass units u). Note that u is based on the mass of the carbon-12 atom which has 12u. Thus a neutron or proton has mass approximately 1u. This is the energy holding the protons and neutrons together inside the nuclide. There is no binding energy for a single neutron or proton, but there would be internal binding energy holding the RBY units together. Note that mass and energy are equivalent by Einstein's equation $E = mc^2$. As a result, the less nuclide mass the more binding energy, which is the sum of the proton and neutron (nucleon) masses minus the nuclide mass given by experiment.

In the classical physics the binding energy is derived from the strong force of gluons and quarks and (residual strong force) pions, but in the crystal theory it comes in another way, which is still being worked out from the connections in the crystal. This is preliminary data that should help later work and it still needs checking.

6.2 Observations

There are some observations:

1. The binding energy per nucleon (proton or neutron) increases with the atom's size up to about 0.008.
2. The binding energy of tritium is more than helium-3 even though tritium decays into helium-3 when a neutron changes to a proton. However, the

total mass of tritium is very slightly more than He-3 and this leads to a release of energy when the conversion takes place.

3. The binding energy of He-4 is abnormally large. This makes perfect sense in the crystal model because there are many connections in He-4 (the complete s subshell).
4. A way to determine the binding energies directly from the crystal still has to be worked out but it should involve some formula with types of connection between the subparticles such as deuterons, protons and neutrons. Also, the number and sizes of shells is important. A more "rounded" shape appears more stable with higher binding energy.

6.3 Table of binding energies

Nuclide	**Number of Proton**	**Number of Neutron**	**Mass Proton**	**Mass Neutron**	**Mass Nuclide**	**Binding energy (u)**	**Binding Energy/(#P+#N)**
Proton	1	0	1.00783	0	1.00783	0	0.00000
Neutron	0	1	0	1.008665	1.008665	0	0.00000
Deuteron	1	1	1.00783	1.008665	2.01355	0.00239	0.00119
Helium-3	2	1	2.01456	1.008665	3.01603	0.007195	0.00241
Helium-4	2	2	2.01456	2.01732	4.00153	0.03035	0.00759
Tritium (12.3y)	1	2	1.00783	2.01732	3.01605	0.0091	0.00287
Lithium-6	3	3	3.02184	3.02598	6.015	0.03282	0.00547
Lithium-7	3	4	3.02184	4.03464	7.016	0.04048	0.00578
Beryllium-7(53d)	4	3	4.02912	3.02598	7.017	0.0381	0.00544
Beryllium-9	4	5	4.02912	5.0433	9.0122	0.06022	0.00669
Boron-10	5	5	5.0364	5.0433	10.013	0.0667	0..00667
Boron-11	5	6	5.0364	6.05196	11.009	0.07936	0.00721
Carbon-12	6	6	6.04368	6.05196	12.	0.09564	0.00705
Carbon-13	6	7	6.04368	7.06062	13.003	0.1013	0.00779
Carbon-14(5730y)	6	8	6.04368	8.06928	14.0032	0.10976	0.00784
Nitrogen-14	7	7	7.05096	7.06062	14.003	0.10858	0.00776

Nitrogen-15	7	8	7.05096	8.06928	15.0001	0.12014	0.00801
Oxygen-16	8	8	8.05824	8.06928	15.99	0.13752	0.00859
Oxygen-17	8	9	8.05824	9.07794	16.99	0.14618	0.00860
Oxygen-18	8	10	8.05824	10.0866	17.99	0.15484	0.00860
Fluorine-19	9	10	9.06552	10.0866	18.99	0.16212	0.00853
Fluorine-22	9	13	9.06552	13.11258	22.002	0.1761	0.0080
Neon-20	10	10	10.0728	10.0866	19.992	0.1674	0.00837
Neon-21	10	11	10.0728	11.09526	20.993	0.17506	0.00834
Neon-22	10	12	10.0728	12..10392	21.99	0.18672	0.00849

Table 6.1 Binding Energies of Nuclides

Chapter 7 Mathematical Properties of the Crystal

The strange thing about physics is that for the fundamental laws we still need mathematics.

(Richard Feynman)

7.1 Charge formula

The electrical charge of a particle in the crystal is induced by the number of its positrons R each having a charge of 1, and the number of its electrons Y, each having a charge of –1. This gives us the formula C = R–Y, where C is the charge, R is the number of R tetrahedra in the particle and Y is the number of Y tetrahedra.

However, it is well-established in physics that charge is a surface property: it accumulates on the surface of an object and can be determined there. This appears to be a contradiction to the above formula which depends upon the internal structure.

There are other places where forces act in strange ways. For example, the gravitational force of an object depends only upon the centre of mass (which is usually entirely within the object). This is the total opposite of the way that electrical forces act, which do so from their surfaces.

We can remedy the false impression that there is a contradiction with charges here.

7.2 Surface charge theorem

The surfaces in the crystal are clearly the union of fundamental faces, isosceles triangles which have one long edge and two short edges in the ratio of 2: $\sqrt{3}$.

With respect to the three colours R, B, Y there are 6 kinds of faces: Rb, Br, Ry, Yr, By, Yb. For example, Rb means a face of a red tetrahedron that has an adjacent black tetrahedron. Can we determine the charge of a particle from the number of these kinds of faces on its surface? Yes, we can!

Theorem 7.1: Given any particle made from R, B, Y tetrahedra,

$$C = R - Y = (Ry - Yr)/2.$$

Proof: Count the number of faces in the particle A in various ways. Firstly, since every R tetrahedron has 2 adjoining Y's and 2 adjoining B's, we deduce

$$2R = Ry \text{ (inside A)} + Ry \text{ (on the surface of A)}$$

Similarly, counting Yr's we obtain

$$2Y = Yr \text{ (inside A)} + Yr \text{ (on the surface of A).}$$

We note that Ry (inside A) = Yr (inside A) because a R and a Y have these two faces in between them. Hence, we subtract one equation from the other and obtain the result. The argument is illustrated in Fig. 7.1.

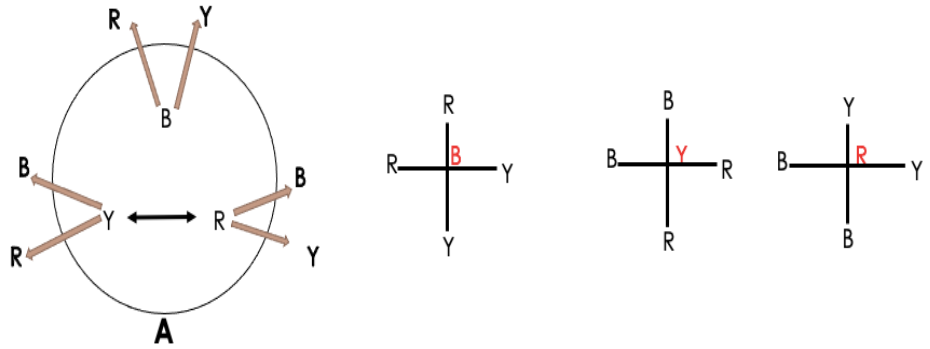


Figure 7.1. A is the crystal bubble particle. The types of vertices of the connection graph are shown.

7.3 A second charge formula

Take a closer look at the crystal and we see that there are two kinds of Ry and Yr faces: either horizontal (the magnetic direction) or vertical (the electrical or energy direction) facing. This observation leads us to another way to calculate the charge. We use a different kind of proof that is called "mathematical induction". The induction is on the total number of R's and Y's in the particle.

Let Ryh, Yrh be the number of horizontal Ry, Yr faces on the particle A's surface respectively. Similarly, let Ryv, Yrv be the number of vertical Ry, Yr faces on its surface respectively.

Theorem 7.2: Given any particle made from R, B, Y tetrahedra,

$$C = Ryh - Yrh = Ryv - Yrv.$$

Proof: Let the particle have f Ryh's and g Yrh's respectively. Let P(n) be the proposition that the charge C of any particle with n = f+g R's and Y's satisfies C = f–g. Then P(0) is true since there are no faces and no tetrahedra and the charge is 0. Suppose that P(n) is true for some integer $n \geq 0$. Then we show that P(n+1) is also true. Assuming P(n), consider some particle A with n+1 R's and Y's. It is obtained from a particle A- with n R's and Y's by adjoining an R or Y. Then C(A) = C(A-) + 1 if an R is adjoined while C(A) = C(A-) – 1 if a Y is adjoined. Note that any R tetrahedron has a unique Ryh face. Assuming an R is adjoined to A-, either it does not have a common Ryh face with A-, in which case the Yrh value of A is unchanged but the Ryh value increases by one, or it does have a common Ryh face with A- and then the value of Yrh decreases by one, and the Ryh value is unchanged. In both cases the value of C(A-) is increased by one and also the value of Ryh–Yrh. The case of adjoining a Y to A- is an identical argument. Hence P(n+1) is true, and the result follows by mathematical induction. There is a similar argument to show the formula for vertical Ryv and Yrv faces, since every R or Y also has a unique such vertical face.

7.4 A surface spin formula

Here we describe a similar way to the charge formulas that finds the spin of a particle also by looking at surface spins. We do this only very concisely. First, one can label the vertices of the crystal with the numbers 1,2,3,4 so that every tetrahedron has these four numbers. The spin of a tetrahedron (R, B or Y) has a

spin ± ½ that is determined by the orientation of this numbering. Notice that two tetrahedra with a common face say 1,2,3 have fourth vertices 4 with opposite orientation or spin.

Similarly, a face e.g. Ry of a tetrahedron can be assigned an associated spin, which is derived from the orientation of the numbers say 0,1,2 in a clockwise direction or an anticlockwise direction when looking from the outside of the tetrahedron. A mirror reflection (of opposite spin) of a tetrahedron will have all its faces of opposite spin to the first tetrahedron.

When two tetrahedra meet at a common face clearly the spins of the common face will cancel out, as in the proof of Theorem 7.1. Hence, we have the following:

Theorem 7.3: The spin of any particle made from R, B, Y tetrahedra can be calculated by knowing the spins of its faces on its surface.

Proof: We leave the details of definitions of the actual spins of faces and the rest of the proof to the reader.

7.5 Delta particles

The Delta particles are types of baryons made from three quarks (in the standard model) that are interesting from an historical standpoint in that having spin 3/2 and masses just a bit bigger than the spin ½ protons and neutrons they were somehow very similar but needed to be explained. The charges of this group of similar particles ranged from –1 to 2. Of course, their antiparticles ranged in charge from –2 to 1. So, there were 4 of these particles and 4 corresponding antiparticles. They were soon explained by having them made from three quarks of the same spin, instead of 3 quarks, two of the same spin and one of the opposite spin which give the proton and neutron. The crystal model has no quarks so how can we explain the Delta's?

The first idea is to make a heavier version of the proton or related neutron YBR by adding something. This something should not be too heavy such as a B and so the obvious way (to get a spin 3/2 object) must be to add an R and a Y to the B. This fills all four faces of the B and the resulting particle should be a Delta of charge 0. There is an anti-Delta particle of charge 0 and this could be obtained in various ways, such as the proposition that there are two kinds of B's (those in protons and those in neutrons). In any case there is a possible particle in the crystal that could be the Delta-0 and clearly it has spin 3/2 as we illustrate below.

Just as the proton is obtained from the neutron by positing a "free" electron, one can posit that the other charged Delta's are obtained from the neutral Delta-0 by removing R's and Y's. The spin of such a particle would be induced by its neutral parent. Following are some tables giving proposed structure and formulas for the Delta's with an indication of the quark structure in the standard model.

Notice that this gives a better indication of the mass of the particles than the standard model which relies more on the binding energy of the internal strong force gluons and much less on the masses of the quarks that make up these baryons. It is predicted from this crystal model (in analogy with the neutron being slightly heavier than the proton) that the mass of the Delta-0 is slightly more than the masses of the children charged Delta particles. However, we don't have a good model for mass in the crystal at present. See Table 7.2 that follows.

Anti-Delta's (right-handed)	Model in the crystal	Equality or not	Delta particles (left-handed)	Model in the crystal	Charge
$\overline{\Delta^{--}}$	R RB	=	Δ^{++} uuu	R RB	2
$\overline{\Delta^{-}}$ $\overline{ddd}$	R RB Y	≠	Δ^{+} (excited P^{+}) uud	R RBY	1
$\overline{\Delta^{0}}$	R RBY Y	≠	Δ^{0} udd	R RBY Y	0
$\overline{\Delta^{+}}$ $\overline{duu}$	RBY Y	≠	Δ^{-} ddd	RBY Y	-1
$\overline{\Delta^{++}}$ $\overline{uuu}$	BY Y	=	Δ^{--}	BY Y	- 2

R
RBY
Y

spin positron (R) =1/2
spin electron (Y) =1/2
spin dark matter (B) = –1/2

Delta-0 has 5 tetrahedra: two positrons (R), two electrons (Y) and one dark matter (B).

Δ spin $= 1/2 + 1/2 + 1/2 + 1/2 - 1/2 = 3/2$

Table 7.2 Formulas for Delta Particles

7.6 Leptons

Following is a table that gives a conjectural model for the three generations of leptons (electrons, positrons, neutrinos, anti-neutrinos etc.). Since there are 6 kinds of triangular faces in the crystal it could be posited that they correspond to the 6 kinds of neutrinos. Then the muons and tau particles (heavier versions of the electrons) could be electrons with some kind of dark matter adjoined, either as a surface element such as triangles or solid tetrahedra B.

In the table we also give some ideas about how the protons, neutrons and pions are formed in the crystal. Pions are important in the standard model as the carriers of the residual strong gluon force that holds the protons and neutrons together in the nuclides. In the crystal theory the pions should be RY, RB and YB's linking across between the various RBY's that are the neutrons and protons. If a muon is a YB then it may be related by a rotation to a pion YB. This might explain the decay of a pion into a muon via the weak force, just as a neutron decays into a proton via the weak force and this is explained in the crystal model by a similar rotation.

There are six kinds of triangles Ry, Yr, By, Br, Yb, Rb in the crystal theory. Perhaps they are neutrinos as shown in Table 7.3.

Basic Particles (Hadrons)	Conjectural model For Leptons		Spin	Parity
	Leptons	Anti-leptons		
Proton P^+ = RBY (RY rhombus horizontal)	ν_e = **Ry**	$\bar{\nu}_e$ = **Yr**	$\pm 1/2$	± 1
Neutron N° = RBY (RY rhombus vertical)	ν_μ = **Rb**	$\bar{\nu}_\mu$ = **Yb**	$\pm 1/2$	± 1
Deuteron PN	ν_τ = **By**	$\bar{\nu}_\tau$ = **Br**	± 1	± 1
Pion π^+ = R/B (Overlap P, N positions, related to residual strong force, parity -1)	e^- = **Y**	e^+ = **R**	$\pm 1/2$	± 1
π^- = Y/B (parity -1)	μ^- = **YB**	μ^+ = **RB**	$\pm 1/2$	± 1
Neutral pion π° = R/Y or RYB or YRB (parity -1)	τ^- = **B** **B Y**	τ^+ = **RB** **B**	$\pm 1/2$	± 1

Table 7.3 Conjectural Models

Chapter 8 Fractals in Mathematics and in the crystal

I think therefore I am *(R. Descartes)*

8.1 Definition of fractals in mathematics

In mathematics, fractals appear the same at different scales, as illustrated in successive magnifications of the Mandelbrot set. Fractals often exhibit similar patterns at increasingly smaller scales, a property called self-similarity, also known as expanding symmetry or unfolding symmetry. If this replication is the same at every scale it is called affine self-similar. The crystal has this kind of property.

8.2 Fractals in the crystal

Inside the crystal there is a particle, call it Y^2, illustrated in Fig. 8.1. It is distinguished by having a yellow tetrahedron Y on each of its 4 corners. It also contains 2 B's and 2 R's. Thus, it contains 8 tetrahedra and its dimensions are exactly twice those of a standard Y, B or R tetrahedron. That is why we have the superscript 2 to distinguish it. Similarly, there are also black and red versions B^2 and R^2.

An easy way to build a Y^2 is to take a standard deuteron made from a proton and a neutron (of the same spins 1) joined together, making sure it is a deuteron with Y's at each end (there is another sort with R's at each end). Then we append two Y's appropriately to two sides of the deuteron. This means that the charge of Y^2 is –2. Similarly, the charge of R^2 is +2, and B^2 has charge 0. They all have spin 0. Notice that the larger particle Y^2 has dimensions in proportion to Y so that is it is the same kind of tetrahedron but of twice the size.

Notice that there is a fractal transformation involved here. We are increasing everything by a factor of two, the charges, the dimensions of the crystal. The spins are different. We notice that we can continue this process forever and expand by powers of two so that Y^{2^h} and the other coloured particles are defined. Clearly, the process could go in the opposite direction as well, so that negative h's define a fractal crystal in which the dimensions become smaller and smaller. Since the crystal is the same at any dimension we could redefine a spin that is suited for that dimension only.

8.3 Pictures of the larger particles (Y^2, R^2, B^2)

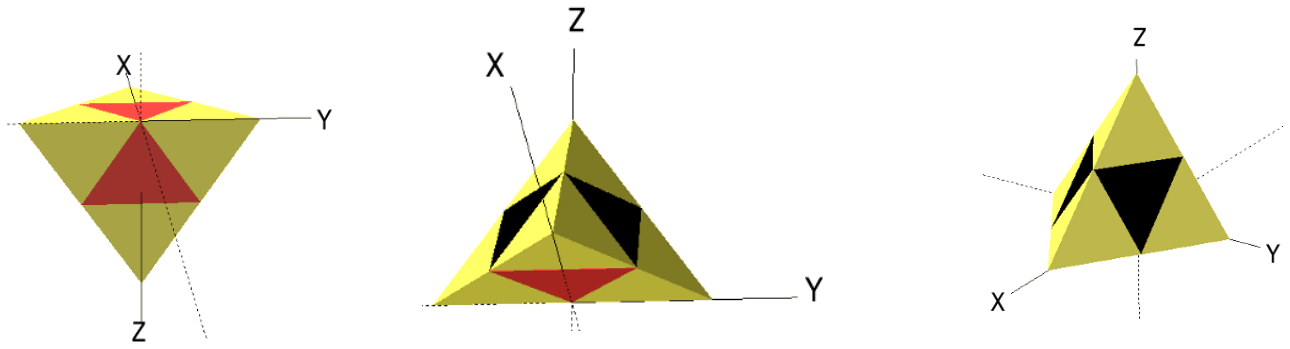


Figure 8.1. This particle Y^2 (shown from 3 different angles) is made from eight tetrahedra: six of them in a deuteron, plus two electrons. Its charge is –2. The deuteron has a spin +1 and each electron has a spin –1/2 (from the inter-connections happening between them) and so the spin for the whole particle is 0.

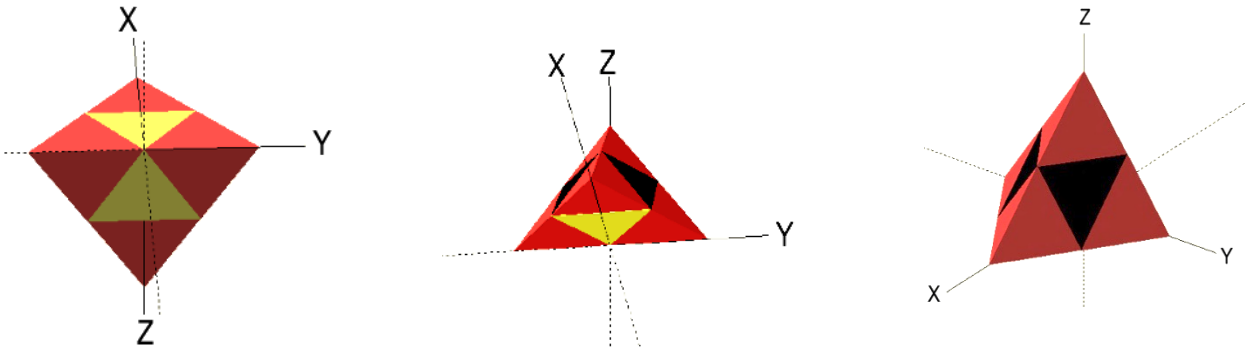


Figure 8.2. This particle R^2 is a deuteron plus two positrons. The charge is +2 and the spin is 0.

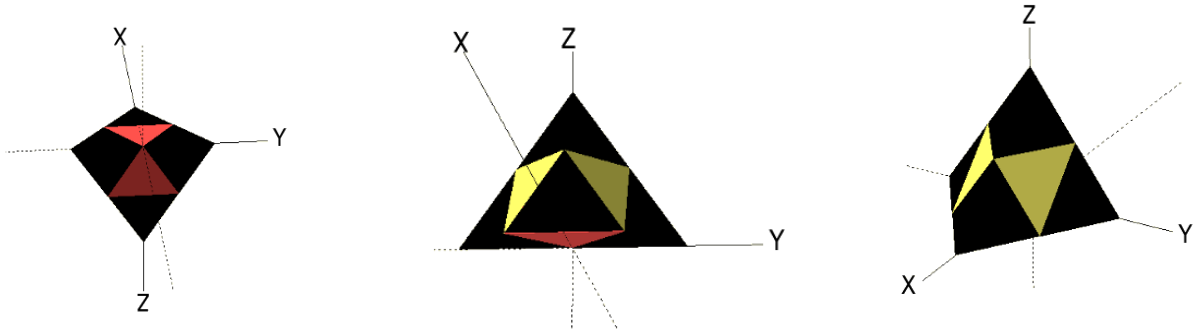


Figure 8.3. This particle B^2 is made from 4 B's, 2 Y's and 2 R's. Its charge is 0 and its spin is 0.

8.4 Sierpinski triangle

This kind of planar fractal is named after the Polish mathematician Waclaw Sierpinski but appeared as a decorative pattern many centuries before the work of Sierpinski. The Sierpinski triangle is formed when one takes a triangle and subdivides it into four smaller triangles found when we join up the mid-points of each side of the first triangle. Continuing this process going to smaller and also larger dimensions in powers of 2 forms the fractal. If we consider a fixed plane in the crystal through one side of any tetrahedron, we can obtain this Sierpinski triangle fractal.

8.5 Tetrix (Sierpinski Tetrahedron)

The crystal model also has the 3-dimensional Tetrix characteristic, which is the manner of building up larger tetrahedra by putting them together, and also subdividing a tetrahedron into 8 smaller ones as we have discussed in Section 8.2. This also shows that the Tetrix has this colouring into R, B and Y colours that is just like the crystal.

Chapter 9 Carbon

Truth is ever to be found in simplicity, not in the multiplicity and confusion of things. *(Isaac Newton)*

9.1 Biological elements

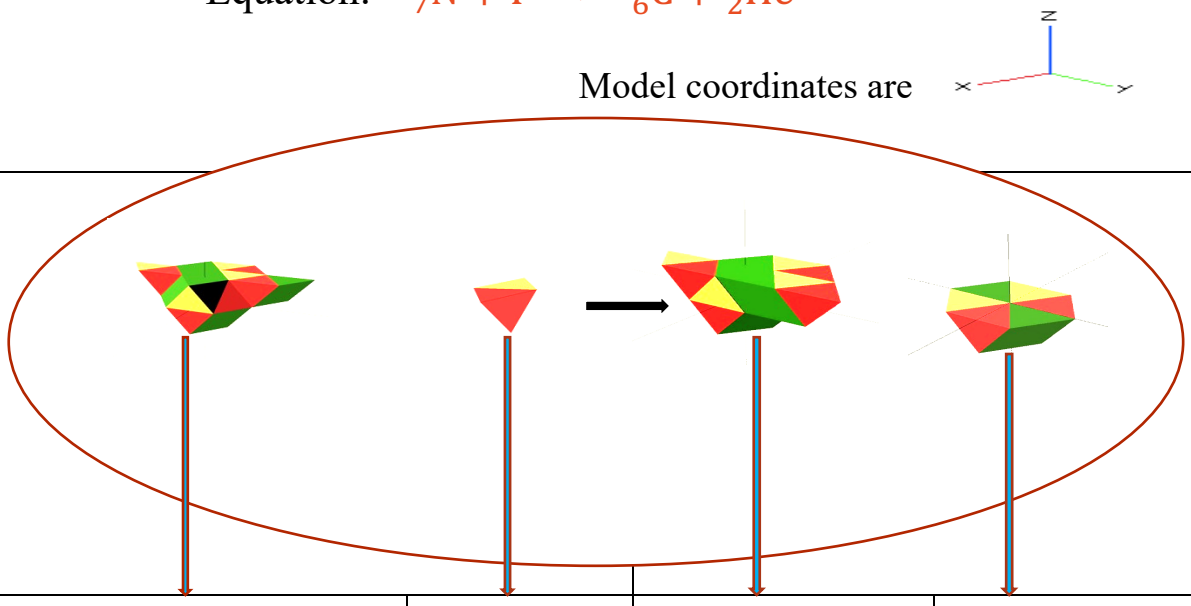
We are made from "organic" elements such as carbon, oxygen and hydrogen. It has been discovered that early on in the universe there was (and still is) a lot of hydrogen (or protons), which formed into helium He-4. After much time stars formed and the He-4 was fused into larger elements. From this process, by fusing together 3 He-4 atoms carbon-12 was generated in large amounts, and this is one of the fundamental building blocks of all known life forms.
Here we look at various kinds of carbon and how the processes involving carbon can be modelled in the crystal.

9.2 Carbon-11 (C-11)

First, we look at another isotope of carbon, C-11. It is produced by a simple process, when an energetic proton (in an atomic accelerator) hits a nitrogen nucleus and splits it into C-11 and an alpha particle (He-4 nuclide). C-11 has a reasonably long half-life of about 20 minutes and is commonly used as a radioisotope in medicine or in biochemistry. It decays into Boron-11 by the emission of a positron. See Fig. 9.1.

Equation: $^{14}_{7}\mathrm{N} + \mathrm{P} \rightarrow {}^{11}_{6}\mathrm{C} + {}^{4}_{2}\mathrm{He}$

Model coordinates are



Nitrogen-14 (N-14) Spin 1, parity +1 Formula is 01|01234	Proton (p) Spin ½, parity +1 Formula is 0a	Carbon-11 (C-11) Spin 3/2, parity -1 Formula is 01|015a7	Helium-4 (He-4) Spin 0, parity +1 Formula is 01

Table 9.1 Carbon-11 production

Table 9.1 shows the reaction between the particles that produces carbon-11. In the crystal theory the nitrogen-14 atom has the formula 01| 01234 and carbon-11 has the formula 01| 0125a7. To produce carbon-11 from nitrogen-14 one needs to add one proton 0a to nitrogen-14. Then these particles turn into carbon-11 and helium-4. Carbon-11 has several benefits: it is possible to include carbon-11 in a lot of organic molecules without any impact. It also has a useful half-life of about 20 minutes that is not too short and not too long.

9.3 Carbon-12 (C-12)

Now we discuss the production of the main stable carbon isotope.

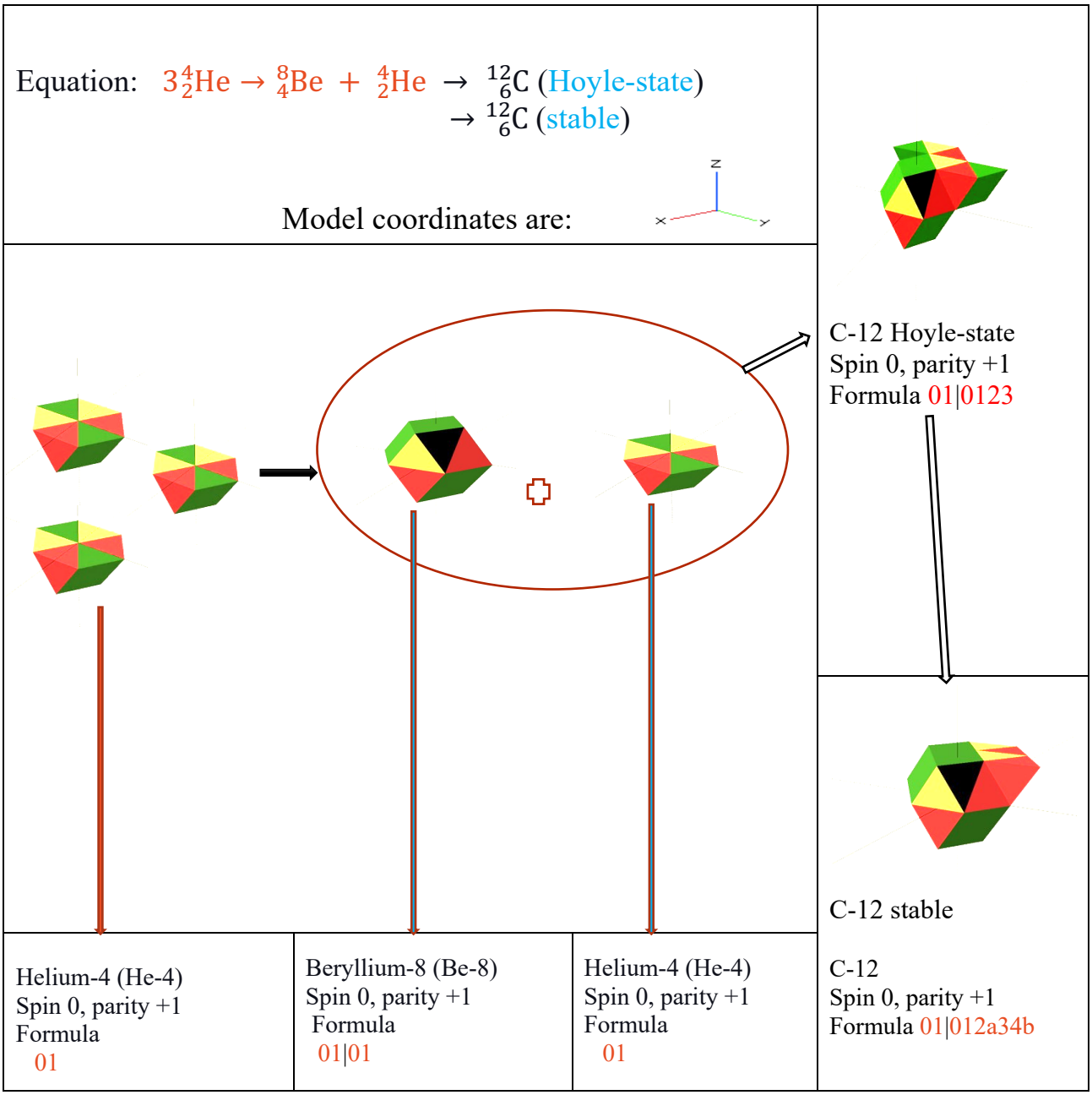


Figure 9.2 Carbon-12 production

In Fig. 9.2 first two He-4's combine (in a star) to give the extremely unstable Be-8. Mostly this splits back again into the 2 very stable heliums. In a few cases another He-4 combines with Be-8 giving the quite unstable Hoyle state of C-12 (a nuclear isomer). Then the Hoyle state changes via a small shift in its configuration to the stable C-12 atom which has six protons and six neutrons and has the formula 01|012a34b. Carbon-12 is the basis of the atomic mass scale with unit u: 1 Avogadro number (1 mole) of C-12 atoms equals exactly 12 grams mass, which means that the mass of one carbon-12 atom is 12u ($dalton = \mathrm{u}$) [9].

9.4 Carbon-14 (C-14)

There is another carbon isotope C-14 that is very useful indeed. It is mainly used for working out the age of organic materials that contain this isotope.

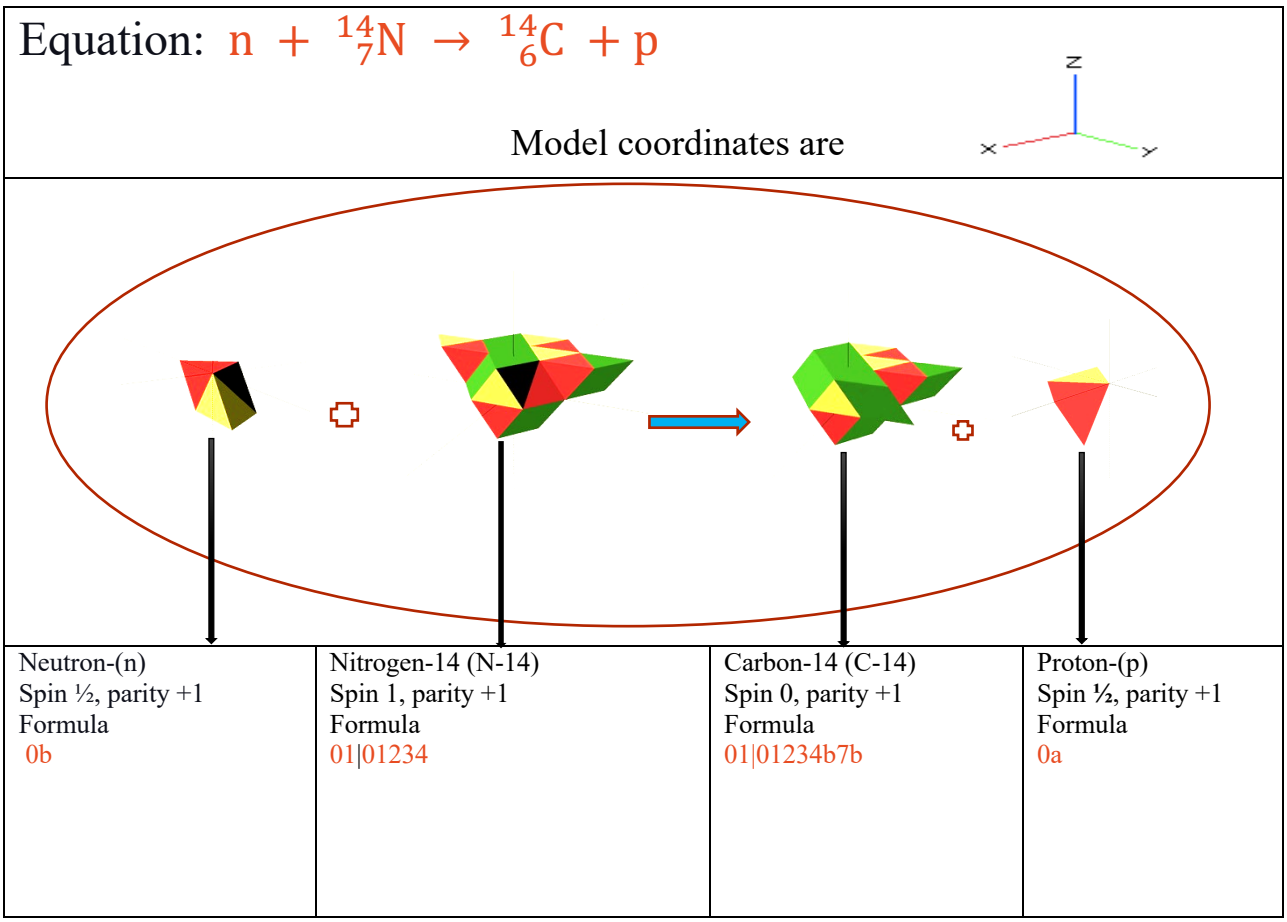


Figure 9.3 Carbon-14 production

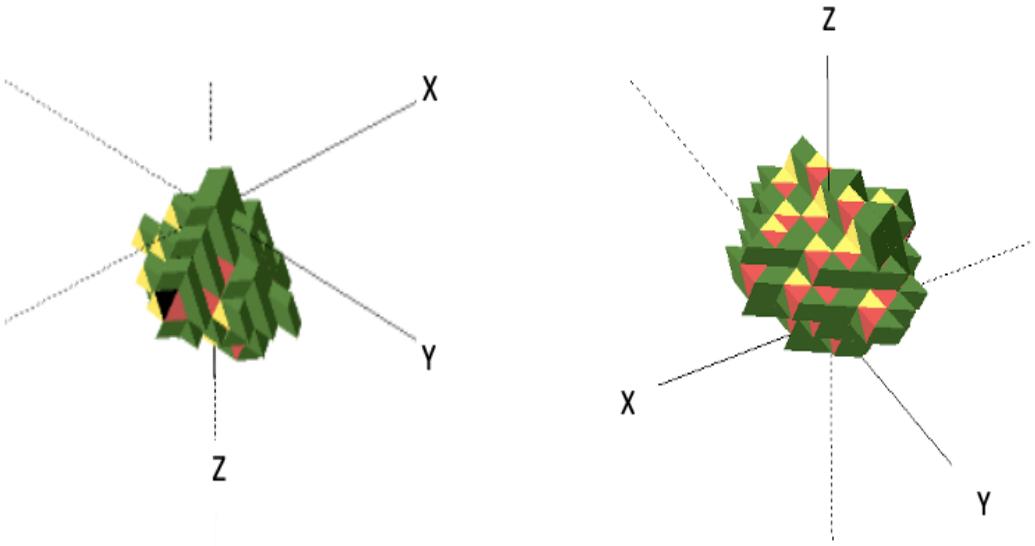
Fig. 9.3 clarifies the reaction in the earth's atmosphere that happens between neutron 0b and nitrogen-14 01|01234. This means a proton 0a replaces the neutron 0b. As a consequence, from this reaction a carbon-14 atom and one proton are produced.

Chapter 10 Bismuth and Appendix

10.1 Bismuth-209

Bismuth is one of the heaviest (almost) stable elements with a measured half-life of 19 exa-years (over a billon times the age of the known universe). It has 83 protons and 126 neutrons. Note that 126 is called a “magic number” in nuclear physics, because that number of nucleons appears to be more stable with more binding energy. Moreover, bismuth-209 has several unique properties. It is a nitrogen-like element but it behaves like a metal such as lead although it is less poisonous. It is also diamagnetic, which means it repels magnetic fields like a super conductor. Consequently the electrons are forming pairs of opposite spin. In our crystal model all the electrons of Bi-209 are paired in orbitals except for those in shell 6 (the top layer). This is forced because of the very high nuclear spin of 4 ½. But these electrons may be free to move and pair because of the metallic nature of Bismuth. This is in spite of Hund’s rule which indicates that electrons do not prefer to pair in the outer shell. Note that our crystal model has all 5 electrons unpaired which conforms with Hund’s rule. We display the nuclear isomer that appears most stable to us. There are four possibilities of isomer that we have found, and they are all listed in the Table 5.1. The parity of –1 is also catered for in the crystal model.

We made a model of Bi-209 out of wood and a picture of this is shown in the Appendix 10.2.



Spin 9/2, Parity -1
Electron shells: 2,8,18,32,18,5
Formula is 0 1 2b 3b 5b 6b| 0 1 2 3 4 5 6 7 9b 10b 12b 14b 16b 17b|0-17 18b 19b 20b 21b 22b 25b 26b 27b 28b 30b| 0-31 33b 35b 38b 40b 42b 44b 47b 49b |0-17 18b 19b 0b 21b 23b 25b 26b 27b 28b 30b| 0 2 4 8 12 24b plus one of the four options 1b 17b, 3b 19b, 3b 23b or 19b 23b.
On the left-hand side the model is upside down.

Figure 10.1 Bismuth diagram and formula in the crystal

Note the 4 possible configurations of 2 neutrons in the top shell. One of these 1b 17b is probably the most stable, because its crystal model is more compact, giving more binding energy. It is the one modelled in the Appendix.

10.2 Appendix: Photograph of Crystal Models

By sawing and gluing wood (30mm square cross-section) we made wooden models of many of the elements. Pictured here are the models of the neutron N^0

or its rotated relative the proton P^+, deuterium D, lithium Li-7, boron B-10 and B-11, C-12 (stable isomer), C-12 (unstable Hoyle isomer), fluorine F-22 (unstable), sodium Na-23 and the very large but "almost" stable bismuth Bi-209 which has an abnormally large spin of 4 ½ . In our model this is derived entirely from the configuration in the top (outer) shell: viz. 5 deuterons of the same spin 1 (total spin 5) and a neutron of spin ½ contiguously positioned in the same straight tube, accompanied by 2 neutrons of spin – ½ each (total spin –1) attached to the side of the tube.

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